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ABSTRACT

Instructional research is synthesized, using categories specific and functional enough to provide guidance for classroom practice. The opening chapter presents a theory for conducting a theory-based meta-analysis of the research on instruction, outlining a theory that involves four elements of human information processing: the self-system, the metacognitive system, the cognitive system, and knowledge. Chapter 2 describes the ways in which these four elements are represented in permanent memory. In chapter 3, the four elements and their subcomponents are described in detail. Chapter 4 describes specific design features of the meta-analysis, and chapters 5 through 8 present the results of the meta-analysis. Chapter 9 contains a general discussion of the findings in terms of classroom practice. In all, the meta-analysis used more than 4,000 effect sizes that involved an estimated 1,237,00 subjects. One observation that results from the meta-analysis is that the self-system appears to be the control center for human behavior, while the metacognitive system is the engine of learning. Three relatively straightforward implications are drawn. The teacher should: (1) identify knowledge and skills that are targets of instruction; (2) identify and use specific instructional techniques for specific instructional goals; and (3) use instructional techniques that apply to all types of instructional goals. (Contains 47 tables, 25 figures, and 398 references.) (SLD)

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A Theory-Based Meta-Analysis of Research on Instruction

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CHAPTER 1

THE NEED FOR A THEORY-BASED REVIEW OF THE RESEARCH

An educator trying to make sense of what research has to say about instruction is faced with a daunting task. First, the sheer number of studies is prohibitive. For example, in their review of the research, Hattie, Biggs, and Purdie (1996) identified over 21,000 studies one would have to consult to undertake an exhaustive review of the literature on the myriad factors that affect student achievement. Even if the sheer number of studies were not so overpowering, the variation in the types of studies that fall under the general heading of "research on instruction" is staggering. For example, studies like those conducted by Cohen (1995), which deal with the effects of specifying learning outcomes, would be classified as instructional research as would studies like those conducted by Palincsar and Brown (1984, 1985) on the effectiveness of a specific comprehension strategy. This is also the case with studies like those conducted by Johnson and Johnson (Johnson and Johnson, 1987; Johnson, Johnson, and Holubec, 1987) on the effectiveness of learning in groups.

Clearly a synthesis of the research on instruction could be of great benefit to educators. However, research reviews in education are not uncommon. Indeed, publications such as *Review of Educational Research* and *Review of Research in Education* routinely include research syntheses of various aspects of instruction, as do journals that are more subject-specific. Many of these synthesis efforts have used a method of review referred to as "the narrative approach" (Glass, 1976; Glass, McGaw and Smith, 1981; Rosenthal, 1991a; Rosenthal and Rubin, 1982).

Within the narrative approach, a researcher attempts to logically synthesize the findings from a collection of studies on a given topic by looking for patterns in the studies reviewed. Unfortunately, the narrative approach is highly susceptible to erroneous conclusions. To illustrate, in a seminal study of the quality of narrative reviews, Jackson (1978; 1980) concluded the following:

- reviewers tend to focus their analyses on only part of the full set of studies they found;
- reviewers commonly used crude and misleading representations of the findings of the studies;
- reviewers usually report so little about their method of reviewing that no judgment can be made about the validity of their findings;
- reviewers commonly fail to critically review the methods used in the studies they review.

In 1980, Cooper and Rosenthal conducted an experiment that dramatically demonstrated the shortcomings of the narrative method of research synthesis. About 40 graduate students were randomly split into two groups. Subjects in both groups were given seven empirical studies to review on "gender differences in persistence." Group A was given directions that would engage them in a narrative analysis of the studies. Group B was given the directions reported in Figure 1.1 that were designed to ensure a more quantitative approach based on the conversion of results to a common z-score metric:

> Before drawing any final conclusions about the overall results of persistence studies, you are asked to perform a simple statistical procedure. The procedure is a way of combining the probabilities of independent studies. The purpose of the procedure is to generate a single probability level that relates to the likelihood of obtaining a set of studies displaying the observed results. This probability is interpreted just like that associated with a *t*- or *F*-statistic. For example, assume the procedure produces a probability of .04. This would mean there are 4 chances in 100 that a set of studies showing these results were produced by chance. The procedure is called The Unweighted Stouffer method, and requires that you do the following:
>
> (1) Transfer the probabilities recorded earlier from each study to Column 1 of the Summary Sheet. (A summary sheet was provided each subject. The sheet contained the titles of the seven articles and columns for performing each step in the procedure.)
>
> (2) Since we are testing the hypothesis that females are more persistent than males, divide each probability in half (a probability of 1 becomes .5). If a study found *men* more persistent, attach a minus sign to its probability. Place these numbers in Column 2. (It had been determined before hand that only two-tailed probabilities were reported.)
>
> (3) Use the Normal Deviations Table provided below and transform each probability in Column 2 into its associated Z-score. Place these values (with sign) in Column 3. If the probability is .5, the associated Z-score is zero (0).
>
> (4) Add the Z-scores in Column 3, keeping track of algebraic sign. Place this value at the bottom of Column 3.
>
> (5) Divide this number by the square root of the number of studies involved. In this case, because N = 7, this number is 2.65. Thus, divide the sum of the Z-scores by 2.65. Place this number in the space below.
>
> Z-SCORE FOR REVIEW __________
>
> (6) Return to the Normal Deviations Table and identify the probability value associated with the Z-score for review. Place this number in the space below.
>
> P-VALUE FOR REVIEW __________
>
> This probability tells how likely it is that a set of studies with these results could have been produced if there really were no relation between gender and persistence. The *smaller* the probability, the *more* likely it is that females and males differ in persistence, based on these studies (1980: 445).

Figure 1.1. Directions to Group B.

At the conclusion of the study, subjects in both groups rated their opinion of the strength of support for a relationship between gender and persistence. The results are reported in Table 1.1.

Table 1.1
Results of Research Synthesis

	Group A Traditional Methods of Review		*Group B Statistical Method of Review*	
Opinion (Is there a relationship?)	No.	%	No.	%
Definitely No	3	14	1	5
Probably No	13	59	5	26
Impossible to Say	5	23	8	42
Probably Yes	1	4	5	26
Definitely Yes	0	0	0	0
		100%		100%

The results were disturbing. Nearly 75 percent of the reviewers who used the narrative method concluded that gender and persistence were not related, whereas only 31 percent of the group using the statistical method described in Figure 1.1 concluded that the two variables were not related. In fact, the combined results of the seven studies supported rejection beyond the .02 level of the null hypothesis that gender and persistence are not related. In short, the vast majority of the reviewers who had used the narrative approach to synthesizing the research had falsely concluded that no relationship existed; whereas only a minority of reviewers who used the statistical approach supported this erroneous conclusion. As Glass, McGaw, and Smith (1981) note, these are "rather strikingly different conclusions for equivalent groups trying to integrate only seven studies" (p. 17). Based on consistent findings that the narrative approach to research synthesis produces unreliable conclusions, more statistically-based methods of research synthesis have been pursued (see Durlak, 1995; Hedges and Olkin, 1985; Wolf, 1986). One of the most popular of these statistically-based methods is meta-analysis.

It was Glass and his colleagues who popularized the statistical approach referred to as meta-analysis (Glass, 1976, 1978; Glass and Smith, 1979; Glass, McGaw, and Smith, 1981). In brief, as defined by Glass, when conducting a meta-analysis the research translates the differences between experimental and control groups on the dependent measure into a standardized metric referred to as an "effect size." Glass defined an effect size using the following formula:

$$\text{effect size} = \frac{\text{experimental } x - \text{control } x}{\text{standard deviation of control}}$$

The advantage to translating the difference between experimental and control groups into this metric is that effect sizes can be compared across studies that use vastly different dependent measures. For example, in their analysis of 13 studies that produced 22 different effect sizes for the relationship between psychotherapy and asthma, Glass et al. (1981) report an average effect size of .85. One of the more useful aspects of the effect size metric is that it is standard deviation units and can, therefore, be interpreted as a change in the percentile ranking of the "average" subject in the experimental group. For example, the reported effect size of .85 can be interpreted in the following way: The mean score of subjects in the experimental groups is .85 standard deviations above the mean of subjects in the control group. Therefore, the average student in the experimental group is at the 80th percentile of the control group — an increase of 30 percentile points. This is depicted in Figure 1.2.

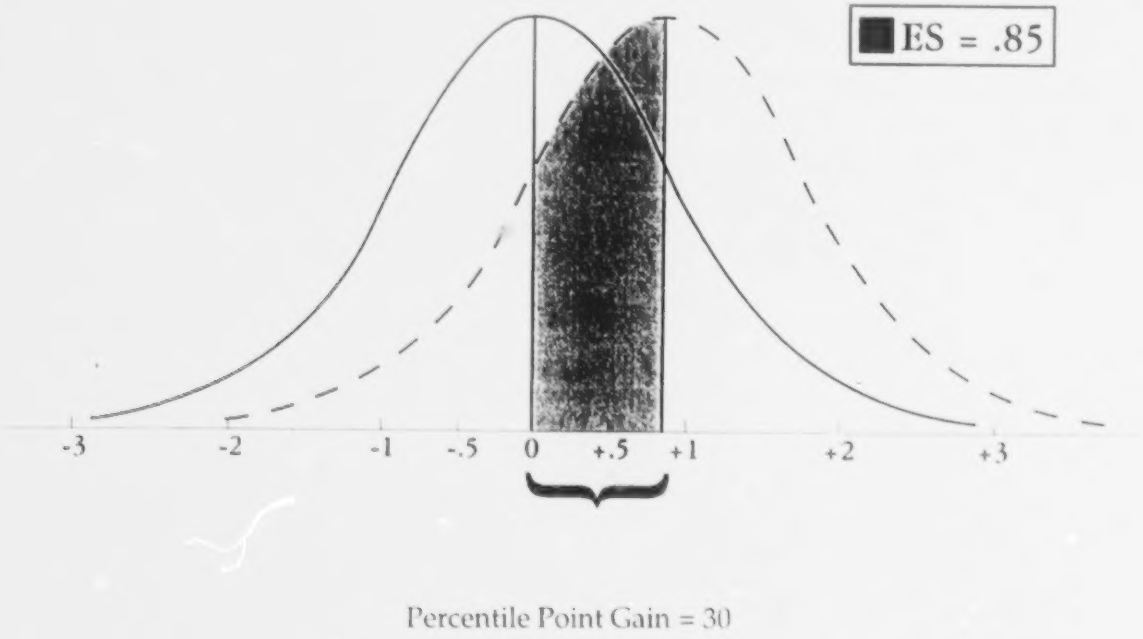

Figure 1.2. Depiction of Effect Size.

Because of its synthetic power, meta-analysis has increased geometrically in use since its inception, and some of its more ambitious applications have been conducted on the research on factors that affect student achievement. As mentioned previously, the meta-analysis of Hattie and his colleagues (Hattie, 1992; Hattie, Biggs and Purdie, 1996) included over 21,000 studies. The meta-analysis by Fraser et al. (1987) involved 7,827 studies.

Unfortunately, in spite of the quantitative objectivity that meta-analysis brings to a review of research, it is still susceptible to a number of problems — one of the most troublesome of which is the "apples and oranges" problem. According to Wolf (1986), the apples and oranges problem occurs when a meta-analyst groups independent or dependent variables into a single, overly general category. For example, if a researcher reviewing studies in psychotherapy lumps studies on the effects of cognitive behavioral modification with studies on the effects of psychoanalysis into a single category, the research would have fallen prey to the apples and oranges problem — cognitive behavioral therapy and psychoanalysis are not similar enough to be included in the same category. The effect size for psychoanalysis is, therefore, inappropriately combined with the effect size for cognitive behavioral modification — the composite effect size tells one very little. Indeed, this is one of the criticisms of Smith, Glass, and Miller's (1980) meta-analysis of therapy techniques (see Presby, 1978). The apples and oranges problem can be so severe that it provokes researchers to provide strong disclaimers on their findings. For example, in his meta-analysis of studies on reading comprehension, Short (1985) provided the following comment on the effects of the apples and oranges problem relative to the conclusion that might be drawn from the study:

> Our experience showed that we came up with average gain effect scores for subcategories that were virtually meaningless because of the diversity of studies which we knew were in a specific category. Studies were in a category such as inference which defined inference differently, used different techniques to teach inference, had various kinds of methodological problems, and used different kinds of dependent measures. Knowing that the category of inference has a specific mean gain effect score, therefore, does not mean anything unless one looks closely at the studies that went into that cell. (Short, 1985, p. 24)

The apples and oranges problem also appears to be prevalent in the meta-analysis conducted to date on instructional research. For example, in his study, Hattie (1992) organized the instructional research into the following categories:

Team teaching
Individualization
Audio-visual aids
Programmed instruction
Ability grouping
Learning hierarchies
Calculators
Instructional media
Testing
Computer-assisted instruction
Simulation and games
Questioning
Homework
Tutoring
Mastery learning
Bilingual programs
Acceleration
Direct Instruction

These very general categories are based on what might be called the "brand name" approach. That is, in this approach, categories represent the popular labels given to sometimes complex interventions with many salient features. For example, "mastery learning" is considered almost a brand name for a specific set of assumptions, instructional techniques, and assessment practices designed by Bloom and his colleagues (Bloom, 1968, 1971, 1984; Block, 1971, 1974; Guskey, 1980, 1985, 1987). However, considering mastery learning as a category in itself might mask differences in the effects of the various elements found within that intervention. Is it the corrective feedback inherent in mastery learning that positively influences student learning, or is it the identification of specific learning objectives? In short, brand name categories are so broad that they tend to mask the effects of the specific strategies embedded within them. In short, they fall prey to the apples and oranges problem.

The Fraser et al. (1987) meta-analysis also used very broad categories that might be considered brand names as the basis for organizing research on instruction. Fraser and his colleagues synthesized the results of 134 meta-analyses that covered 7,827 separate studies involving 5 to 15 million subjects. In all, 22,125 effect sizes were computed or reported. Again, the general categories masked some important differences between instructional techniques. For example, Fraser et al. reported the effect size of "modern math" as .24. However, this specific effect size was based on a meta-analysis conducted by Athappilly, Smidchens, and Kofel (1983). When one analyzes the Athappilly et al. study in depth, it quickly becomes apparent that different strategies within the brand name "modern math" had different effect sizes. For example, use of manipulatives had an effect size of .51; direct instruction in concepts and principles had an effect size of .35; and use of an inquiry approach had an effect size of only .04.

The meta-analyses by Wang, Haertel, and Walberg (1993) attempted to use categories that were more functional in nature. These categories included:

- classroom implementation support
- classroom instruction
- quantity of instruction
- classroom assessment
- classroom management
- student and teacher social interactions
- student and teacher academic interactions
- classroom climate

Unfortunately, these categories are still too broad. For example, the category of classroom management might include a score of specific instructional techniques all with very different effect sizes.

What appears needed is a meta-analysis that utilizes more discrete categories that are specific enough to provide guidance for educators in terms of classroom practice. This need was addressed in the 1986 publication by the U.S. Department of Education entitled *What Works: Research About Teaching and Learning* (U.S. Department of Education, 1986). In a preface to that report, then President Reagan wrote, "In assembling some of the best available research for use by the American public, *What Works* exemplifies the type of information the Federal government can and should provide" (p. iii). Indeed, the report did identify a few specific instructional techniques. However, by design, the report provided only a sample of what more comprehensive studies could and should produce (p. 2).

The need for more specific categories with which to organize the research on instruction has more recently been provided by educational researchers. Specifically, after decades of studies on instruction, educational researchers have concluded that practitioners simply have not benefitted from the knowledge that has accumulated from those thousands of studies primarily because that research has not been presented in such a way as to be readily interpretable in terms of classroom practice (Robinson, 1998; Kennedy, 1997).

This study seeks to synthesize the extant instructional research — much of which has been included in other meta-analyses — using categories specific and functional enough to provide guidance for classroom practice.

There is, of course, a plurality of categories that can be used to organize the instructional research. For this study, categories are based on a theory of human information processing. A basic assumption of this effort is that a theory will quite naturally produce categories with which to organize instructional research that are inherently discrete and provide guidance for classroom practice. The theory used here is an adaptation of that designed by Marzano (Marzano, 1997; McCombs and Marzano, 1990).

The utility of a theory as the basis from which to conduct a meta-analysis on instructional research is best understood if one considers the differences between frameworks, theories, and models. Anderson (1983) explains the distinctions in the following way:

> A framework is a general pool of constructs for understanding a domain, but it is not tightly enough organized to constitute a predictive theory. . . A theory is a precise deductive system that is more general than a model... A model is the application of a theory to a specific phenomenon, for instance, performance of mental arithmetic. (1983, pp. 12-13)

A second basic assumption of this study is that previous meta-analyses of the research on instruction have not organized the independent variables using a theory or a model. At best, they have utilized loose frameworks which produced overly general categories. As we have seen, this practice renders a meta-analysis highly susceptible to the "apples and oranges" problem. Instructional techniques that would be classified separately under the rubric of a theory might be classified together under the rubric of a loose framework. The theory used here is intended to provide a tight classification system for instructional techniques as well as to predict human behavior in some detail.

Before continuing, it is important here to note the level at which the theory presented in this work is articulated. Anderson (1990a) explains that theories can be articulated at a number of levels. Theories at the computational level articulate the goals of a particular function and the general strategies within it; theories articulated at the algorithmic level specify the steps involved in the strategies articulated at the computational level. Theories articulated at the hardware level identify how algorithms can be represented physically (i.e., neurologically or as computer code). The theory presented here is best described as a very general computational theory. Specific steps in processes are not described; however, general strategies are.

The theory used for this meta-analysis posits the interaction of four aspects of human thought operating in most, if not all, situations: (1) knowledge, (2) the cognitive system, (3) the metacognitive system, and (4) the self-system. Figure 1.3 depicts the interaction of these four elements from the time a presenting task is initiated until it is completed.

In this theory, a presenting task is defined as any externally generated or internally generated stimulus to change the status quo. For example, a student in a mathematics class might be daydreaming about an upcoming volleyball game after school and be asked by her teacher to pay attention to the new information that is being presented about mathematics. The request to pay attention to mathematics is an externally generated stimulus to change the status quo. Similarly, the student daydreaming about volleyball might independently conclude that it would be a good idea to pay attention to the new information about mathematics. This conclusion, that it is perhaps more advisable to pay attention to mathematics than to continue daydreaming, is an internally generated stimulus to change the status quo. In both cases, the student engages her self, metacognitive, and cognitive systems as well as her knowledge. Each of these four elements is discussed in depth in Chapter 3. Here, they are briefly introduced.

The self-system contains a network of interrelated beliefs that enable one to make sense of the world (Markus and Ruvulo, 1990; Harter, 1980). Additionally, the self-system contains processes that evaluate the importance of the presenting task relative to a system of goals, and assesses the probability of success relative to the individual's beliefs (Garcia and Pintrich, 1991, 1993, 1995; Pintrich and Garcia, 1992). If the presenting task is judged as important and the probability of success is high, positive affect is generated and the individual is motivated to engage in the presenting task (Ajzen, 1985; Ajzen and Fishbein, 1977, 1980; Ajzen and Madden, 1986). If the presenting task is evaluated as low relevance and/or low probability of success, negative affect is generated and motivation for task engagement is low. In this later case, compensatory activities are selected, one of which might be to continue the status quo.

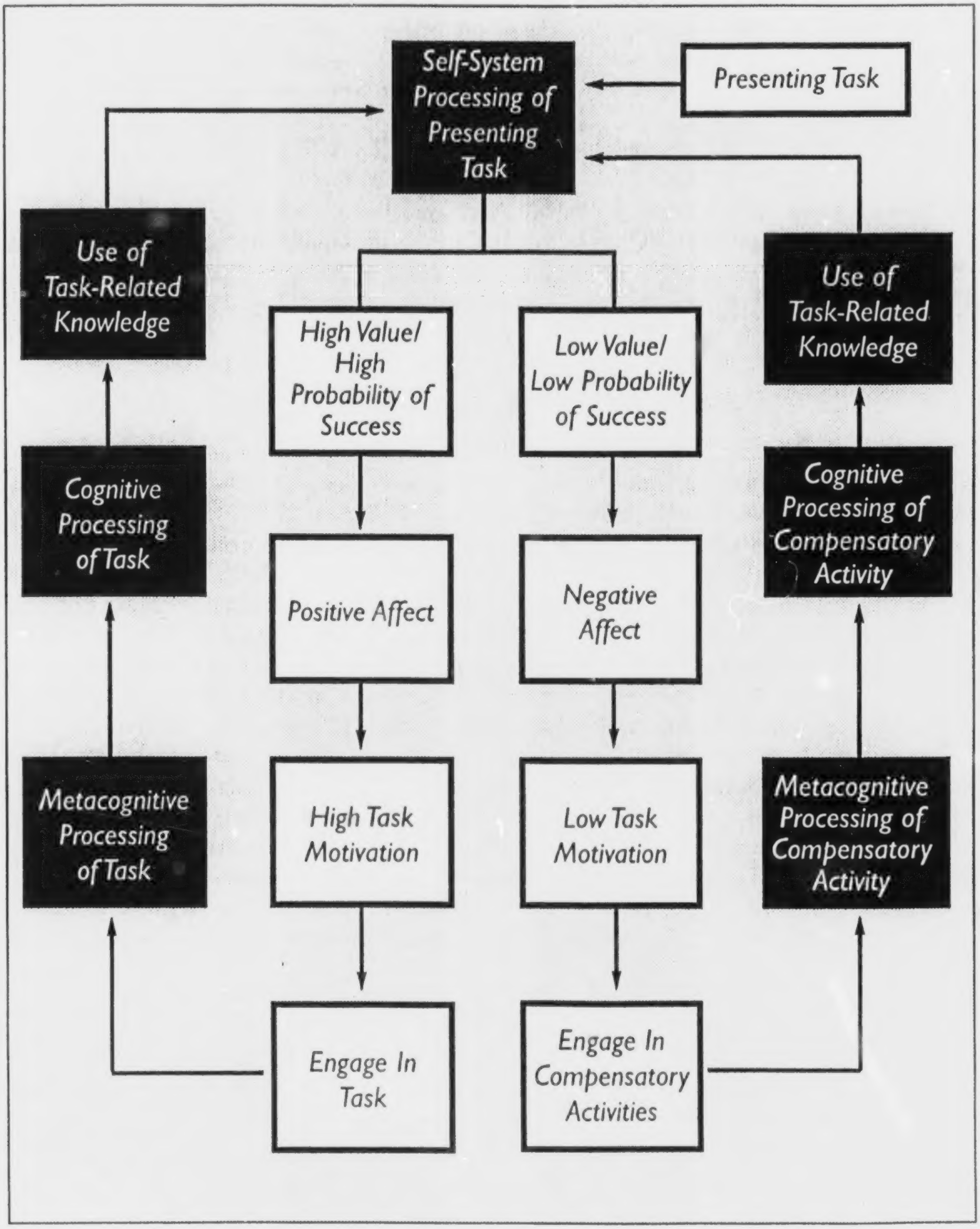
Self-System Processing of Presenting Task
Presenting Task
Use of Task-Related Knowledge
High Value/ High Probability of Success
Low Value/ Low Probability of Success
Use of Task-Related Knowledge
Cognitive Processing of Task
Positive Affect
Negative Affect
Cognitive Processing of Compensatory Activity
Metacognitive Processing of Task
High Task Motivation
Low Task Motivation
Metacognitive Processing of Compensatory Activity
Engage In Task
Engage In Compensatory Activities

Figure 1.3. Interaction of Four Elements of Thought.

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Because the mechanisms in the self-domain are the working elements that define motivation and volition in human behavior, they have historically been referred to as "conative" structures (Snow and Jackson, 1993) where conation is defined as "the part of mental life having to do with striving, including desire and volition" (Flexner and Houck, 1987, p. 422).

Regardless of whether the presenting task or compensatory activities are selected, the metacognitive system is engaged. This system contains information about the nature and importance of plans, time lines, resources and their interactions (Schank and Abelson, 1977). This system is also responsible for designing strategies for accomplishing a given goal once it has been set (Sternberg, 1977, 1984a, 1984b, 1986a, 1986b). The metacognitive system is continually interacting with the cognitive system throughout the task.

The cognitive system is responsible for the effective processing of the information that is essential to the presenting task. For example, if the presenting task requires solving a problem, the cognitive system is responsible for the effective execution of the steps involved in problem solving. If the presenting task requires the generation of a novel idea, the cognitive system is responsible for the construction of the new concept. The processes within the cognitive system act on an individual's knowledge base (Anderson, 1995; Lindsay and Norman, 1977).

Relative to any given presenting task, knowledge is the information and skill that is specific to the task. For example, if the presenting task is to pay attention to new mathematics information, then the cognitive system will activate and act upon the knowledge the student already possesses about mathematics. If the presenting task is to read an article about the Vietnam war, then the cognitive system will activate the knowledge the student possesses about Vietnam.

Again, each of these four elements is described in depth in Chapter 3. For now, it suffices to recognize that each of the four elements (and their subcomponents) depicted in Figure 1.3 is necessary for effective learning. Stated negatively, a breakdown in any one of the elements within any one of the three systems or knowledge can render a learning situation unproductive. For example, if a student has no personal goals within the self-system that would allow the student to interpret the presenting task as important, the student might select compensatory activities in lieu of engaging in the presenting task. If the student does not have effective goal-monitoring procedures in the metacognitive system, the chances of completing the presenting task are severely compromised. If the student does not effectively process and utilize information necessary to the task via the cognitive system, the task will be executed inefficiently. Finally, if the student does not possess knowledge critical to the completion of the task, her efforts will surely falter.

Given their relevance, all four elements and their subcomponents are legitimate targets of instruction and, therefore, legitimate filters through which to interpret the research on instruction.

Summary and Preview of Chapters

In this chapter, a rationale has been presented for conducting a theory-based meta-analysis of the research on instruction. Additionally, the outline of a theory was presented that involved four elements of human information processing — the self-system, the metacognitive system, the cognitive system, and knowledge. In Chapter 2, the manner in which these four elements are represented in permanent memory is described. In Chapter 3, the four elements and their subcomponents are described in detail. Chapter 4 describes specific design features of the meta-analysis, Chapters 5 through 8 present the results of the meta-analysis, and Chapter 9 provides a general discussion of those results in terms of classroom practice.

The reader not interested in the intricacies of the theory underlying the meta-analysis might skip Chapters 2 and 3. However, even though the content of those chapters is presented using some technical terminology, an understanding of the theory base that undergirds this meta-analysis effect will greatly enhance the reader's understanding of the findings.

CHAPTER 2

THE REPRESENTATIONAL MODALITIES

To understand the self-system, the metacognitive system, the cognitive system, and knowledge, it is first necessary to discuss the manner in which these elements are represented in memory. This chapter describes the three representational modalities or "modes" that are the building blocks of the three systems and knowledge. The three representational modes are: (1) the linguistic mode, (2) the nonlinguistic mode, and (3) the affective mode. Each of the four elements introduced in Chapter 1 is represented mentally in one or more of these three modes. For example, an individual's knowledge of mathematics, let's say, will certainly be represented linguistically and nonlinguistically and possibly even affectively.

It is useful to think of these three modalities as the products of innate processors. That is, all information that is perceived via the senses passes through three processors and is encoded as linguistic, nonlinguistic, or affective representations. The relationship of the three processors to the information perceived through the senses is depicted in Figure 2.1.

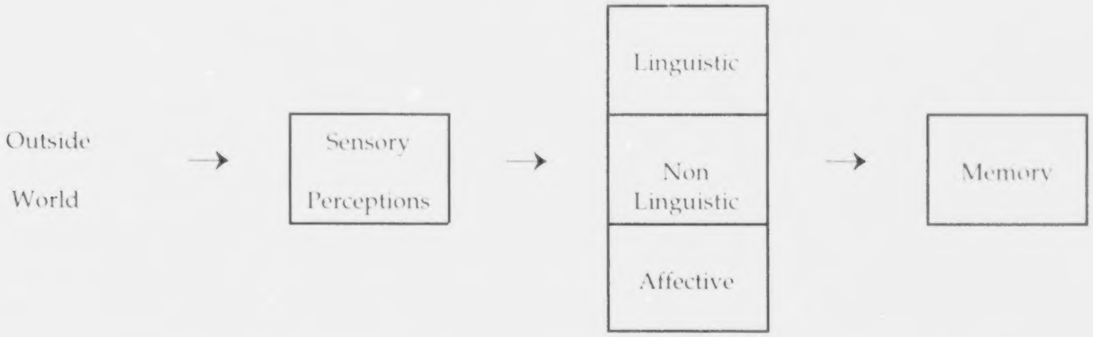

Figure 2.1. Processors.

To illustrate the flow of information depicted in Figure 2.1, assume that an individual goes to a bullfight for the first time — an experience from the outside world. The first type of information she receives about this new experience will be raw sensory data. However, this data will be quickly encoded in one or more of the three forms. She might encode this sensory data linguistically — as information about bullfights. She might also encode the experience as nonlinguistic data — as mental images and sensations about the bullfight. Finally, she might encode the experience affectively — as strong emotions about the experience. Anderson (1995) likens these multi-model representations of sensory experiences to "records." Each experience an individual has is encoded and filed away as one or more records.

The data in the cognitive system, metacognitive system, self-system, and knowledge briefly mentioned in Chapter 1 are made up of structures that contain linguistic, nonlinguistic, and affective components. To this extent, the three representational modalities can be considered the "building blocks" of the mind.

In this chapter, each representational modality is considered in some depth. Their relationship to the self-system, the metacognitive system, the cognitive system, and knowledge is discussed in the next chapter.

The Linguistic Modality

It is probably safe to say that the linguistic mode is the one that receives the most attention from an educational perspective. Knowledge is most commonly presented linguistically and students are most commonly expected to respond linguistically.

The nature of the linguistic processor has been discussed for decades. Arguably, the discussion became most prominent in the late 1950s, when Noam Chomsky published *Syntactic Structures* (1957). There he posited the existence of an innate language mechanism (i.e., linguistic processor) possessed by all human beings. The function of the linguistic mechanism was to translate experiences into linguistically-based structures. Chomsky expanded on and defended his theory in a number of later works (Chomsky, 1965, 1975, 1980, 1988). Most recently, Stephen Pinker has expanded on Chomsky's theory in his book *The Language Instinct* (Pinker, 1994).

One of Chomsky's basic tenets was that language study should proceed from the recognition of the difference between language competence and language performance. Language competence refers to the language user's understanding of and innate ability with language. Language performance addresses the actual use of language in specific situations.

Chomsky viewed the fundamental problem of linguistic study as that of "determining from the data of performance the underlying system of rules that has been mastered by the speaker-hearer and that he puts to use in actual performance" (Chomsky, 1965, p. 3). Perhaps Chomsky's most powerful explanatory construct was his differentiation between two types of linguistic structures — surface structures and deep structures. The surface structure of language deals with the actual use of language and is the measure of the language user's performance. The deep structure of language deals with the underlying semantic and syntactic nature of language and is the measure of competence. The initial insight Chomsky elucidated in *Syntactic Structures* was that sentences must be characterized by two structural descriptions, not one, as would be the case with grammar systems that were designed prior to Chomsky's work (i.e., the traditional grammar that is commonly taught in school). This insight was clarified and generalized in *Aspects of a Theory of Syntax*, published in 1965.

The necessity for the two forms is most easily seen with imperatives. The "surface structure" *Go away* is understood by ordinary speakers as a realization of the underlying form or deep structure: *You will go away.* Based on Chomsky's theory, linguists such as Kellogg Hunt (1965) began to describe the process by which surface structures are transformed into deep structures and vice versa. In fact, the application of Chomsky's theory came to be known as "transformational grammar." Chomsky's deep structure theory allows one to operationally define the nature of the language processor. The task of the language processor is to transform experiences and surface-level languages into a deep structure representation.

The actual format of deep structure representations of experience has been the subject of much discussion. The most popular model for describing the basic unit of thought within the deep structure representation of experience is the proposition. The construct of a proposition has a rich history in both psychology and linguistics (Frederiksen, 1975; Kintsch, 1974; Norman and Rumelhart, 1975). In simple terms, "a proposition is the smallest unit of thought that can stand as a separate assertion, that is, the smallest unit about which it makes sense to make the judgment true or false" (Anderson, 1990b, p.123). Clark and Clark (1977) have noted that there is a finite set of the types of propositions. Figure 2.2 depicts the major types of propositions.

1. Max walks.
2. Max is handsome.
3. Max eats fruit.
4. Max is in London.
5. Max gave a toy to Molly.
6. Max walks slowly.
7. Max hit Bill with a pillow.
8. Sorrow overcame Max.

Figure 2.2. Major Types of Propositions.

Each of the statements in Figure 2.2 can be affirmed or denied, yet none of their component parts can. That is, one could determine if it is true that *Max walks* or *Max is handsome*, but one could not confirm or deny *Max, walks, is,* or *handsome* in isolation. Propositions, then, might be described as the most basic form of a complete thought within the linguistic system of thought.

Case grammarians like Fillmore (1968) and Chafe (1970) and psychologists like Turner and Greene (1977) have described the various components of a proposition. Basically, every proposition contains a verb (technically referred to as a goal) and elements that are related to that verb. In the proposition *Max walks, walks* is the verb. Verbs are either states or actions. The elements that are related (technically called the "arguments" of a proposition) can have a number of functions including those listed in Figure 2.3.

Agent:	The animate being that causes the action identified by the goal. (*Max* in the proposition, *Max walks.*)
Receiver:	The animate being affected by the action of the goal. (*Molly* in the proposition, *Max gave a toy to Molly.*)
Instrument:	The object used to facilitate the action of the goal. (*Pillow* in the proposition, *Max hit Bill with a pillow.*)
Locative:	The place in which the action identified by the goal occurs or where any of the arguments in a proposition reside. (*London* in the proposition, *Max is in London.*)
Motive:	The inanimate reason for the action or state expressed in the goal. (*Sorrow* in the proposition, *Sorrow overcame Max.*)
Manner:	The manner in which an action or state occurs. (*Slowly* in the proposition, *Max walks slowly.*)
Object:	The inanimate object affected by the action of the goal. (*Fruit* in the proposition, *Max eats fruit.*)
State:	The state or quality of an argument. (*Handsome* in the proposition, *Max is handsome.*)

Figure 2.3. Types of Arguments Within Propositions.

The format of the basic structure of propositions has led some psychologists to assert that human beings are predisposed or driven to organize experiences in propositional form. Specifically, McNeil (1975) notes that human beings tend to partition their experiences into agents, objects, instruments, and the like, even when experiences do not necessarily fit into these partitionings. Based on this notion, some linguists have conjectured that the basic propositional form of language shapes perception. Whorf's (1956) concept of linguistic relativity epitomizes this assertion. Building on the teaching of Sapir (1921), Whorf proposed that we dissect nature along the lines laid down by our language competence. The thoughts generated from the world of sensory stimuli are not there because they stare every observer in the face: "On the contrary, the world is presented in a kaleidoscopic flux of impressions which has to be organized by our minds — and this means largely by the linguistic systems in our minds" (Whorf, 1956, p.213). Although there is ample research evidence to refute the contention that language determines human perception in an absolute sense (Anderson, 1990b), the fact that language shapes perceptions to some extent is widely accepted among psychologists.

One of the more important features of deep-structure propositions is that their component parts are not filled by words. Rather, Turner and Greene (1977) explain that "word concepts" are the component parts of propositions stored in memory. (To avoid confusion with a subsequent explanation of concepts, the term "abstract concept" will be used in place of Turner and Greene's "word concept.") For example, when an individual stores the proposition (thought) in memory that *fish swim*, the words *fish* and *swim* are not actually stored as the component parts of the proposition. We use words only when we want to express the content of a proposition to ourselves or someone else. As Turner and Greene explain:

> The actual word or words which are chosen to represent the [abstract] concept are word tokens for the [abstract] concept. It is important to understand that the [abstract] concept can and may be represented by a number of words in a given language. (p. 3)

Abstract concepts, then, are the basic components of propositions that are themselves the basic units of deep-structure, linguistic thought. Given the importance of abstract concepts to linguistic thought, it is useful to consider these in some depth.

The Nature of Abstract Concepts

There has been a great deal of research and theory on the nature of abstract concepts (Klausmeier, 1980; Smith and Medin, 1981; Tennyson, 1975). Virtually all of the major discussions of the nature and format of abstract concepts acknowledge the role of semantic features. It was Katz and Fodor (1963) who first popularized the notion that abstract concepts can be defined as sets of semantic features. Unfortunately, to exemplify semantic features as they relate to abstract concepts, one must use words that are not the concepts themselves, only "tokens" for the abstract concepts. With this in mind, consider Figure 2.4 which illustrates the role of semantic features in defining abstract concepts.

The words in set A all represent abstract concepts with the semantic features *human, animal,* and *two-legged*. The words in B_1 and B_2 represent abstract concepts that are differentiated by the fact that all B_1 abstract concepts contain the added semantic feature of *male*, all B_2 words represent abstract concepts with the added semantic feature of *female*. The abstract concepts represented by words in set C do not share a male-female distinction, but they do share a semantic feature that might be called *siblings*.

Semantic feature theory, then, asserts that abstract concepts are defined by sets of semantic features. The abstract concept represented by the word *cow* is defined by semantic features such as *animate, concrete, four-legged, milk-producing*, and so on. The abstract concept represented by the word *desk* is defined by semantic features such as *inanimate, concrete, four-legged, used for paper work*, and so on.

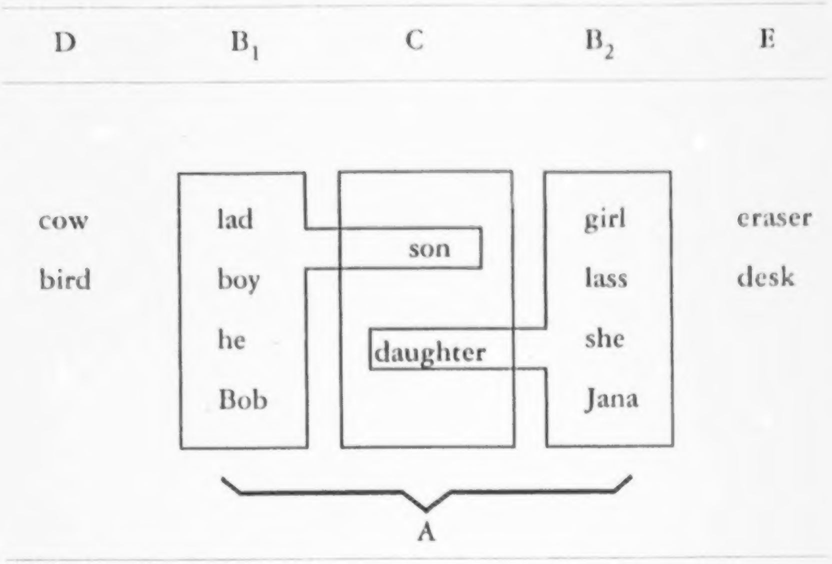

Figure 2.4. Semantic Features.

Words are the tokens or symbols of the abstract concepts an individual knows. Although each word in a language does not represent a distinct abstract concept, the overwhelming majority do. To illustrate, of the 6,768 words identified by Marzano, Kendall, and Paynter (1991) as high frequency "basic words" (i.e., not derived from another word), over 99 percent represent distinct abstract concepts. Although this might sound surprising, even a cursory analysis of words in the English language supports this conclusion. Consider, for example, the words *house* and *home*. Even though they represent abstract concepts that are very close in terms of their characteristic semantic features, the abstract concept represented by *home* would have some unique semantic features that might be stated as *occupied by long-term residents, residents share harmonious existence*. From this discussion one can conclude that learning new words is tantamount to learning new distinctions within a society, which is tantamount to learning new abstract concepts important to a society. This might explain why word knowledge has been shown to be highly correlated with achievement, aptitude, and intelligence (see Nagy, 1988; Nagy and Anderson, 1984; Sternberg, 1987; Sternberg and Powell, 1983; Marzano and Marzano, 1988).

Propositional Networks

Propositions and their constituent abstract concepts do not exist in isolation. Rather, they are organized into interrelated sets or networks. Many psychologists make a distinction between two different types of propositional networks within linguistic thought: declarative networks and procedural networks. For example, psychologists Snow and Lohman (1989) note that "the distinction between declarative and procedural knowledge, or more simply, content knowledge and process knowledge" is one of the most basic in terms of guiding educational practice. (p. 266)

Declarative propositional networks are informational in nature. In a very general sense, they might be described as the "what" of human knowledge. Some psychologists (e.g., Tulving, 1972) assert that declarative networks can be partitioned into two basic categories: episodic and semantic. Episodic networks are those that represent the events we experience. For example, if an individual watched or participated in a football game for the first time, he would represent the information as an episodic network. First one thing happened, then another, the weather was warm, and so on.

Most commonly, the propositions in episodic networks are connected by temporal and causal relationships (Marzano, 1983; Marzano and Dole, 1985). Another characteristic of episodic networks is that they are highly contextualized — they represent specific events individuals have experienced, such as the football game. Conversely, semantic propositional networks contain decontextualized information. For example, an individual might translate the episodic information about the football game into a semantic network that contains propositions like the following: *Football games involve 22 players. The goal of a football game is to move the ball across the opponent's goal line*, and so on. Semantic networks, then, contain information that in large part has been generalized from episodic networks. Where the propositions in episodic networks are commonly related by time and causality, the propositions in semantic networks are commonly related by subordination, coordination, and superordination (Marzano and Dole, 1985; Marzano, 1983).

Procedural propositional networks contain process of knowledge, both mental and physical. They can be described as the "how-to" of human knowledge. For example, an individual's knowledge about how to drive a car or how to do long division is stored as procedural networks. Anderson (1983) has described the basic nature of procedural networks as "IF - THEN" structures called productions. A complex procedure consists of a series of interrelated productions. Below are the first two productions of a procedure for comparing two figures:

P1: IF the goal is to compare object 1 to object 2

THEN set as the subgoal to create an image of object 2 that is congruent to object 1.

P2: IF the goal is to create an image of object 2 that is congruent to object 1 and part 1 is a part of object 1

THEN set as a subgoal to create an image of a part of object 2 corresponding to part 1.

As described by Anderson (1983), this procedure contains 24 productions in all.

Procedural networks can be mental or physical in nature. The example above is mental. An example of a physical procedural network would be the series of steps involved in hitting a baseball.

One distinguishing characteristic of procedural networks is that their effectiveness is a function of the extent to which they have been internalized to the level of automaticity. For example, LaBerge and Samuels (1974) have shown that to be useful, procedural networks used within the process of reading must be learned to the point at which they can be done with little conscious thought or even no conscious thought. Similarly, the more an individual has practiced the mental process of long division (i.e., a procedural network) until he can use it with little conscious effort, the more useful the procedure will be to him. However, due to its complexity, some procedural knowledge never reaches the level of automaticity. Rather, processes that involve a large number of hierarchic, interactive subcomponents usually require conscious thought to be effectively executed. Snow and Lohman (1989) refer to such processes as "controlled," in contrast to automatic processes.

In summary, the linguistic processor encodes experiences as propositions that are abstract in nature. These abstract propositions are organized into networks. At least two distinct categories of propositional networks can be identified. One category, referred to as a declarative network, contains information about specific events and episodes as well as information generalized from them. The second category, referred to as a procedural network, contains information about how to perform specific mental or physical processes.

The Nonlinguistic Modality

The nonlinguistic processor encodes experiences as mental pictures, olfactory sensations (smell), kinesthetic sensations (touch), auditory sensations (sound), and taste sensations. Certainly, the different types of nonlinguistic data originate from different sensory receptors — the eyes provide data for the perception of images, the ears provide data for the perception of sound, and so on. One, then, might conclude that there should be five different modalities — one for each type of sensation. However, the discussion here is not focused on direct sensory perception. Rather, this discussion considers the mental pictures, olfactory sensations, and so on as representations in permanent memory. From this perspective, these sensations are quite similar, if not identical. That is, psychologists have postulated that all types of sensory data (i.e., nonlinguistic representations) function in a similar fashion in permanent memory (Richardson, 1983).

Mental Images

Where the world of cognitive psychology is in general agreement that the proposition is the most useful model for representing linguistic knowledge, many models have been postulated for the structure of mental images. Indeed, the nature of mental images has perplexed psychologists for decades (Pinker, 1997, p. 286).

To understand the nature of mental imagery as it relates to this discussion, it is useful to distinguish among the various types. Psychologist Alan Richardson (1983) distinguishes among four types of images: after-images, eidetic images, thought images, and imagination images. After-images are those images one continues to have after a visual sensation. For example, an individual will have an after-image of a light bulb flash. Eidetic imagery is most commonly thought of as "photographic memory" — the ability to retrieve an image as originally experienced long after the physical data to the eye has been removed. Thought images are those that emanate from permanent memory as opposed to visual stimuli from the eye. That is, thought images are constructed from memory. According to Richardson, they are relatively spontaneous in nature and generally accompany an individual's thoughts without the individual having to consciously construct the images. Imagination imagery is like thought imagery in that it emanates from permanent memory. However, where thought imagery is spontaneous, imagined images are consciously constructed by the individual. For example, to generate an imagination of a blue elephant with yellow stripes, one must consciously engage in its construction. Although after-images and eidetic images are certainly significant aspects of human experience, here the discussion of imagery is limited to thought images and imagination images because they are constructed from the data in permanent memory.

The manner in which images (i.e., thought images and imagination images) are represented is a topic of considerable debate. In their review of the research on imagery representation, Pinker and Kosslyn (1987) identify a number of theories. Two of the pioneering theories about images were cell assembly theories and array theories.

Cell assembly theories (Hebb, 1968) postulated that images are produced by systematic patterns of neural firings. These patterns were referred to as cell assemblies and were assumed to be hierarchic in nature. Lower order assemblies respond to specific visual elements such as edges and lines. Higher order assemblies address the overall design of an image. Pinker and Kosslyn note that Hebb's cell assembly theory was incomplete as originally presented, but provided a good basis for further development. Kosslyn (1980), Schwartz (1979), and Pinker (1980, 1981) posited complementary array theories that had their origins in cell assembly theories. Within these later theories, images were conceived of as patterns of activation of specific cells within a matrix of cells specifically designed for the generation of images. In general, the array theories identified the specific cells that were dedicated to the production of images, where cell assembly theories did not.

It was the work of artificial intelligence researcher David Marr (1982) that has formed the basis of many current conceptions of imagery. As described by Stephen Pinker (1997), Marr's model builds on the array theory but adds considerable detail in terms of the functioning of the arrays that generate images. One of his primary distinctions is what Pinker refers to as the 2½–D theory of imagery. Fundamentally, Marr noted that, counter to what might appear to be common sense, all forms of imagery (i.e., after-images, eidetic, thought, and imagination) are not three-dimensional in nature. Within the 2½–D sketch model, length and width are full dimensions, but depth is downgraded to half a dimension. There are a number of reasons why Marr settled on this model. (See Pinker, 1977, for a discussion.) For the purpose of this work, it is enough to note that the model provides the most flexible explanation of the mechanisms underlying visual imagery. At a practical level, this means that perception of depth is constructed by the perceiver from his knowledge of the situation. Pinker notes that this is why a toddler will never appear bigger than an adult even though the toddler is physically closer. Psychologist Biederman (1995) has expanded on Marr's model postulating a finite set of elementary visual elements (called "geoms" by analogy of protons and neutrons making up atoms). Pinker notes that these elements are much like the basic elements of grammar that are combined to form propositions.

> Geoms are combinatorial, like grammar. Obviously, we don't describe shapes to ourselves in words, but geom assemblies are a kind of internal language. . .Elements from a fixed vocabulary are fitted together into larger structures, like words in a phrase or sentence. (Pinker, 1997, p. 270)

To this extent, then, the nonlinguistic representation of mental images is analogous to the linguistic representation of propositions. What is referred to in this work as a mental image is a 2½–D representation that is generated from long-term memory. As Pinker notes, "A mental image is simply a pattern in the 2½–D sketch that is loaded from long-term memory rather than from the eyes" (Pinker, 1997, p. 286). Images, then, can be generated in two ways — from the eyes and from permanent memory. Again, Pinker notes that the neural system is specifically designed for this two-way flow of data: "The fiber pathways to the visual areas of the brain are two-way. They carry as much information down from the higher, conceptual levels as up from the lower, sensory levels." (Pinker, 1997, p. 287)

Mental images quite obviously are a key aspect of nonlinguistic thought. However, they are not as robust and complete as propositionally-based linguistic information. Using metaphoric terms, psychologist William James noted that mental images are "devoid of pungency and tang" (James, 1890/1950). In similar fashion, Pinker explains that "We recall glimpses of parts, arrange them in a mental tableau, and then do a juggling act to refresh each part as it fades" (1997, p. 294). The fragmented and constructed nature of mental images was illustrated in a simple experiment conducted by psychologists Nickerson and Adams (1979). They asked people to draw both sides of a penny from memory. Even though all subjects had seen a penny thousands of times, the medium number of salient features people recalled was three out of eight. However, when subjects were asked to select elements from a list, they did much better. Surprisingly, when subjects were shown fifteen possible drawings of pennies, fewer than half selected the correct drawing. "Obviously, visual memories are not accurate pictures of whole objects" (Pinker, 1997, p. 295).

Auditory, Kinesthetic, Taste, and Olfactory Representations

Certainly the biology of the sensations of sound, touch, taste, and smell are very different. (For a discussion, see Sheikh, 1983.) However, as mentioned previously, they can be considered quite similar when viewed from the perspective of representations in permanent memory as opposed to the direct physical sensations. Indeed, these sensations are sometimes considered types of images because they exhibit some of the same characteristics. For example, just as there are visual after-images, so, too, are there kinesthetic after-images: "After working for several hours on a small boat, a rocking sensation persists after coming ashore; and after wearing a hat for some time, the pressure of its rim seems to continue after its removal (Richardson, 1983, p. 21).

As mental representations, these sensations have all the characteristics of imagination images. Specifically, they are less robust than direct physical sensations — a smell remembered will be devoid of pungency and tang as well as taste, sound, and touch remembered.

In summary, the nonlinguistic processor represents experiences as mental images, smells, tastes, sounds, and kinesthetic feelings. Although quite different from the perspective of direct sensory experiences, they are quite similar from the perspective of mental representations. All have the defining characteristics of imagination images in that they are constructions of the information in permanent memory and are far less detailed and robust than their sensory counterparts. Consequently, the nonlinguistic representations of an experience will have aspects that are quite vivid and aspects that are quite vapid or even nonexistent.

The Affective Modality

The relationship of affect to thought has been recognized for years by psychologists. For example, Piaget proposed a metaphor likening affect to the gasoline that fuels the engine of the intellect (Bearison and Zimiles, 1986). Any discussion of the affective modality requires some consideration of the physical workings of the brain since affect, by definition, is inherently physiological.

As is the case with imagery, there are a number of different perspectives on the nature of affect. In fact, even the term *affect* is commonly misunderstood. Stuss and Benson (1983) explain that it is best understood in relationship to a set of related terms that include *feeling*, *mood*, and *emotion*. Affect is the broadest term subsuming mood, feeling, and emotion. Feeling refers to one's internal physiological state at any given point in time. The term emotion refers to the combination of feeling and the thoughts that are associated with the feeling. In the terminology of the theory presented in this work, emotions can be understood as the confluence of propositionally-based linguistic data and specific physiological states (i.e., feelings). Finally, the term mood refers to a long-term emotion or the most representative emotion over a long period of time. From these definitions, one might conclude that internal physiological states are the primary elements of feelings, emotions, and moods. What, then, are the characteristics of internal physiological states?

Most brain researchers agree that the limbic system is the part of the brain responsible for internal physiological states (Restak, 1994; Gazzaniga, 1992; LeDoux, 1994; Sylwester, 1995). The limbic system is folded around the brain stem, which, by definition, is located at the top of the spinal cord. It consists of a number of specific organs and elements that include the pituitary gland, the thalamus, the hippocampus, and the amygdala. It is generally believed that the amygdala, an almond-shaped organ buried in each temporal lobe, "houses the main circuits that color our experiences with emotions" — i.e., internal physiological states (Pinker, 1997, p. 371). For the purposes of the discussion here, it is important to note that the limbic system affects virtually every part of the brain. As Damasio and Van Hoesen note, ". . . one might conclude that the limbic system's output is a core element of most activities that take place in the nervous system" (1983, p. 92). To illustrate, Sylwester (1995) explains that the limbic system is central to the execution of such rudimentary processes as how we categorize memories and what we choose to pay attention to. Pinker (1997) notes that the amygdala sends signals to virtually every other part of the brain including the decision-making circuiting of the cortex (1997, p. 372). All of this implies that affective representations permeate human memory.

An understanding of chemical nature of physiological states adds to an understanding of the pervasive nature of affect. It appears that one type of neurotransmitter — peptides — plays a vital role in the determination of internal physiological states (LeDoux, 1994, 1996; Gazzaniga, 1992). The important aspect of peptides, in terms of understanding the nature of affect, is that they modulate our experience of pleasure and pain. Additionally, peptides transmit data not only through the nervous system, but also the circulatory system and air passages, again proving evidence for the robust influence of affect. At the simplest level, then, one's internal physiological state at any point in time can be described as an experience of pleasure or pain. Sylwester (1995) explains that it is best to think of the sensations of pleasure and pain as existing in a continuum. He likens this continuum to the color spectrum.

> If we travel the color spectrum as it gradually moves from red to violet, we note the subtle shifts in color, but we can also stop here and there and identify discrete primary and secondary colors. Such factors as context, hue, and brightness can also affect our perception of a color: we can

> perceive an object as blue against one background and as green against another. So it goes with emotions. (1995, p. 74)

We might conclude, then, that feelings are sensations along a pleasure/pain continuum that are distinguished by factors such as intensity, duration, and so on. The wide variety of emotions that humans experience are actually interpretations of these primary internal states.

A number of scientists have attempted to identify the various emotions into which human beings partition the primary internal physiological states. For example, Tomkins (1962) proposed the existence of eight basic emotions: surprise, interest, joy, rage, fear, disgust, shame, and anguish. Ekman (1992) has a shorter list of basic emotions: surprise, happiness, anger, fear, disgust, and sadness. Plutchik (1980, 1993) has one of the more well-developed theories of emotions. He posits a circle of emotions analogous to a circle of colors in which the mixing of elementary colors results in new colors. As explained by LeDoux, Plutchik's theory can be described in the following way:

> Each basic emotion occupies a position on the circle. Blends of two basic emotions are called dyads. Blends involving adjacent emotions in the circle are first-order dyads, blends involving emotions that are separated by one other emotion are second-order dyads, and so on. Love, in this scheme, is a first-order dyad resulting from the blending of adjacent basic emotions joy and acceptance, whereas guilt is a second-order dyad involving joy and fear, which are separated by acceptance. The further away two basic emotions are, the less likely they are to mix. And if two distant emotions mix, conflict is likely. Fear and surprise are adjacent and readily blend to give rise to alarm, but joy and fear are separated by acceptance and their fusion is imperfect — the conflict that results is the source of the emotion guilt. (1996, pp. 113-114)

Important to the discussion here is LeDoux's commentary that the generation of higher emotions is a psycho social phenomenon — learned interpretation of primary states.

Pinker explains that an awareness of the rudimentary nature of internal physiological states (i.e., emotions, feelings) clears up a great deal of misunderstandings regarding alleged cultural differences in the experience of feelings and emotions. He notes:

> Allegedly, the Utku-Inuit Eskimos have no word for anger and do not feel the emotion. Tahitians supposedly do not recognize guilt, sadness, longing, or loneliness. (Pinker, 1997, p. 364)

Pinker argues that sociologists have erroneously concluded that certain cultures experience some emotions while others do not. But this is not the case: "Cultures surely differ in how often their members express, talk about, and act on various emotions. But that says nothing about what their people feel. The evidence suggests that the emotions of all normal members of our species are played on the same keyboard" (Pinker, 1997, p. 365). The keyboard Pinker refers to is the internal physiological states produced by the limbic system. Stated differently, all cultures experience the same range of physiological states or feelings. However, the extent to which they have names for these states or openly discuss these states differs dramatically from culture to culture. Darwin, too, noted the commonality in feelings. He explained that "The same state of mind is expressed throughout the world with remarkable uniformity, and this fact is in itself interesting as evidence of the close similarity in bodily structure and mental disposition of all the races of mankind." (in Pinker, 1997, p. 365)

In summary, the affective modality is a continuum of internal physiological states that are interpreted as feelings, emotions, and ultimately, moods. The end points of the physiological continuum are pleasure and pain. Different cultures make different distinctions regarding specific types of internal states in terms of the labels they employ and the extent to which they publicly acknowledge their feelings. However, the experience of feelings is probably identical from culture to culture.

The Modularity of the Human Mind

A basic assumption regarding the three modalities described in this chapter is that experiences can and frequently are encoded in memory using all three modalities. That is, experiences are stored or encoded as three dimensional "packets." This modularity assumption is quite consistent with current brain theory. Recall from the introductory comments in this chapter that Anderson (1995) refers to these modular encodings of experience as "records."

The concept that the brain has a modular structure has received a great deal of attention over the last two decades. Gazzaniga (1985) describes the modularity of the brain in the following way:

> By modularity, I mean that the brain is organized into relatively independent functioning units that work in parallel. The mind is not an indivisible whole operating in a single way to solve all problems . . . the vast and rich information impinging on our brain is broken into parts . . . (p. 4)

In his book *The Modular Brain* (1994), Richard Restak details the historical development of the concept of brain modularity, noting that over time it replaced the theory that the brain has a strict hierarchic organization. Restak credits Johns Hopkins neuroscientist

Vernon Mountcastle as the primary architect of the modern modular theory. He cites Mountcastle as saying:

> . . . Most people don't think hierarchically anymore; they shy away from saying "This function resides here." Instead, we now believe the brain is arranged according to a distributed system composed of large numbers of modular elements linked together. That means the information flow through such a system may follow a number of different pathways, and the dominance of one path or another is a dynamic and changing property of the system. (Restak, 1994, p. 35)

The discussion of modularity by Restak, Mountcastle, and Gazzaniga addresses the physical architecture of the brain. Here I refer to the psychological structure of the mind — the structure of stored experience. As discussed previously, a basic assumption of the theory presented in this book is that human experiences are stored in three dimensional modules. For example, if a person goes to a football game, the experience will be encoded as mental pictures, smells, tastes, sounds, and kinesthetic sensations — all forms of nonlinguistic representation. The individual might also store emotions associated with the game such as anger or joy — forms of the affective modality. Finally, the individual will encode the experience as deep-structure propositions describing what occurred — forms of the linguistic modality.

Some psychologists believe that, over time, the linguistic modality becomes the dominant mode of processing. "The behaviors that these separate systems emit are monitored by the one system we come to use more and more, namely the verbal natural language system" (Gazzaniga and LeDoux, 1978, p. 150). The primacy of language was demonstrated in a study by Mandler and Ritchey (1977). Subjects were shown ten pictures, one right after another. Pictures contained fairly common scenes like a teacher at a blackboard with a student working at a desk. After viewing eight such pictures for ten seconds each, subjects were presented with a series of pictures and asked to identify which ones they had seen. The series contained the exact pictures they had studied as well as distraction pictures. Two types of distractors were used, token distractors and semantic changes. Token distractor pictures changed details of the target pictures like the pattern in the teacher's dress. Pictures that contained semantic changes altered some element that was at a high level of importance in terms of the propositional network representing the picture. For example, a semantic change might change the teacher from a male to a female. There was no systematic difference in the amount of physical change in the pictures between token changes and semantic changes. Subjects recognized the original pictures 77 percent of the time, rejected the token distractors only 60 percent of the time, but rejected the semantic distractors 94 percent of the time. In short, subjects had encoded each picture as a linguistically-based set of abstract propositions with an accompanying visual representation. It was the propositional changes in the picture that were best recognized, not the changes in the nonlinguistic aspects of the information.

Conversely, arguments are also made that the emotional system is the primary representational modality. Specifically, a good case can be made for the assertion that the affective modality exerts the most influence over human thought and experience. This case is well articulated in LeDoux's *The Emotional Brain: The Mysterious Underpinnings of Emotional Life* (1996).

Among other things, as a result of his analysis of the research on emotions, LeDoux concludes that human beings 1) have little direct control over their emotional reactions, and 2) once emotions occur, they become powerful motivators of future behavior. Relative to humans' lack of control over emotions LeDoux notes:

> Anyone who has tried to fake an emotion, or who has been the recipient of a faked one, knows all too well the futility of the attempt. While conscious control over emotions is weak, emotions can flood consciousness. This is so because the wiring of the brain at this point in our evolutionary history is such that connections from the emotional systems to the cognitive systems are stronger than connections from the cognitive systems to the emotional systems. (p. 19)

Relative to the power of emotions once they occur, Le Doux explains:

> They chart the course of moment-to-moment action as well as set the sails toward long-term achievements. But our emotions can also get us into trouble. When fear becomes anxiety, desire gives way to greed, or annoyance turns to anger, anger to hatred, friendship to envy, love to obsession, or pleasure to addiction, our emotions start working against us. Mental health is maintained by emotional hygiene, and mental problems, to a large extent, reflect a breakdown of emotional order. Emotions can have both useful and pathological consequences. (pp. 19-20)

For LeDoux, then, emotions are primary motivators that often outstrip an individual's system of values and beliefs relative to their influence on human behavior. This was demonstrated in a study by Nisbett and Wilson (1977) who found that people are often mistaken about internal causes of their actions and feelings. The researchers noted that individuals always provide reasons for their actions. However, when reasoned and plausible reasons are not available, people make up reasons and believe them. As described by LeDoux, this illustrates that the forces that drive human behavior cannot be attributed to the rational conclusions generated by our linguistic mind, but are functions of the inner workings of our emotional mind.

Summary

In this chapter, three representational modalities have been described. The processors that generate these representations can be considered the engines of human thought in that they translate experiences into internal representations in permanent memory. The linguistic processor encodes experiences as propositions organized into declarative and procedural networks. These networks encode the "what" of human knowledge and the "how to," both mental and physical. The nonlinguistic processsor encodes experiences as images, sounds, tastes, smells, and kinesthetic sensations. Finally, the affective processor encodes experiences as chemical reactions that are interpreted as emotions.

CHAPTER 3

SELF, METACOGNITION, COGNITION AND KNOWLEDGE

The three representational modalities described in Chapter 2 provide the backdrop with which to understand the nature of the self-system, the metacognitive system, the cognitive system, and knowledge, in that each of these elements of thought consists of modules that have linguistic, nonlinguistic, and affective components. We consider the knowledge domains first.

The Knowledge Domains

The element of human thought that has been referred to in Chapter 1 as knowledge, is comprised of the information, mental processes, and psychomotor processes that are specific to a given subject matter. For example, the knowledge specific to the subject of geography includes information about various locations, weather patterns, and the influences that location has on the development of a region; the knowledge associated with geography also includes mental processes such as how to read and utilize a contour map, how to read and utilize a political map, and so on. There is probably little, if any, psychomotor knowledge that is specific to geography. Flying, on the other hand, has a significant amount of psychomotor knowledge. For example, a pilot must master the physical skills involved in landing, taking off, and the like. Informational knowledge necessary to be an effective pilot would include an understanding of certain key concepts such as lift and drag. Finally, the mental process knowledge necessary to be an effective pilot would include strategies for efficient scanning and interpretation of an instrument panel.

Given the inherent differences in these types of knowledge, it is useful to think of them as related *domains* of knowledge.

The Domain of Information

The items in the domain of information can be conceptualized as existing in a hierarchy. At the bottom of the informational hierarchy are "vocabulary terms." A vocabulary term is comprised of a word or phrase with associated semantic and/or episodic characteristics that distinguish it from other vocabulary words. As described in Chapter 2, words are the building blocks of propositional networks. At a practical level, it is fairly obvious that students must understand a certain amount of the basic vocabulary in a subject area before they can understand the facts, generalizations, and concepts within a content area. This might explain why teachers frequently must devote a significant amount of time to vocabulary instruction. For example, after analyzing popular textbooks, Bloom (1976) concluded that textbooks commonly introduce as many as 100 to 150 new terms per chapter (p. 25). A level above vocabulary items are facts. Facts present information about specific persons, places, things, and events. To illustrate, "The Dred Scott decision was one of the precipitating events of the Civil War" is a fact. To understand this fact, a student must understand the words (i.e., vocabulary terms) *decision, precipitating, event*, and so on. At the top end of the hierarchy are more general structures such as generalizations and concepts. The statement "Judiciary decisions have been the initiating events for some great conflicts" is a generalization. *Conflict* is a concept.

Although vocabulary terms and facts are important, generalizations help students develop a broad knowledge base because they transfer more readily to different situations. For instance, the generalization above can be applied across countries, situations, and ages, whereas the fact of the Dred Scott decision is a specific event that does not directly transfer to other situations. This is not to say that facts are unimportant. On the contrary, to truly understand generalizations, students must be able to support them with exemplifying facts. For instance, to understand the generalization about judiciary decisions, students need a rich set of illustrative facts, one of which is probably that of the Dred Scott decision.

The full range of elements in the information hierarchy is described in more detail in Figure 3.1.

Vocabulary Terms

At the most specific level of informational knowledge are vocabulary terms. In this system, knowing a vocabulary term means understanding the meaning of a word at a very general level. For example, when a student understands declarative knowledge at the level of a vocabulary term, he has a general idea what the word means and no serious misconceptions about its meaning. To organize classroom content as vocabulary terms is to organize it as independent words. The expectation is that students have an accurate, but somewhat surface-level, understanding of the meaning of these terms.

Facts

Facts are a very specific type of informational content. Facts convey information about specific persons, places, living and nonliving things, and events. They commonly articulate information such as the following:

- The characteristics of a specific person (e.g., The fictitious character Robin Hood first appeared in English literature in the early 1800s).
- The characteristics of a specific place (e.g., Denver is in the state of Colorado).
- The characteristics of specific living and nonliving things (e.g., My dog, Tuffy, is a golden retriever; the Empire State Building is over 100 stories high.).
- The characteristics of a specific event (e.g., Construction began on the leaning tower of Pisa in 1174).

Time Sequences

Time sequences include important events that occurred between two points in time. For example, the events that occurred between President Kennedy's assassination on November 22, 1963, and his burial on November 25, 1963, are organized as a time sequence in most people's memories. First one thing happened, then another, then another.

Cause/Effect Sequences

Cause/effect sequences involve events that produce a product or an effect. A causal sequence can be as simple as a single cause for a single effect. For example, the fact that the game was lost because a certain player dropped the ball in the end zone can be organized as a causal sequence. More commonly, however, effects have complex networks of causes; one event affects another that combines with a third event to affect a fourth that then affects another and so on. For example, the events leading up to the Civil War can be organized as a causal sequence.

Episodes

Episodes are specific events that have (1) a setting (e.g., a particular time and place), (2) specific participants, (3) a particular duration, (4) a specific sequence of events, and (5) a particular cause and effect. For example, the events of Watergate could be organized as an episode. The episode occurred at a particular time and place; it had specific participants; it lasted for a specific duration of time; it involved a specific sequence of events; it was caused by specific events; and it had a specific effect on the country.

Generalizations

Generalizations are statements for which examples can be provided. For example, the statement, "U.S. presidents often come from families that have great wealth or influence" is a generalization, for which examples can be provided. It is easy to confuse some generalizations with some facts. Facts identify characteristics of *specific* persons, places, living and nonliving things, and events, whereas generalizations identify characteristics about *classes or categories* of persons, places, living and nonliving things, and events. For example, the statement, "My dog, Tuffy, is a golden retriever" is a fact. However, the statement, "Golden retrievers are good hunters" is a generalization. In addition, generalizations identify characteristics about abstractions. Specifically, information about abstractions is always stated in the form of generalizations. Below are examples of the various types of generalizations:

- Characteristics of classes of persons (e.g., It takes at least two years of training to become a fireman.)
- Characteristics of classes of places (e.g., Large cities have high crime rates.)
- Characteristics of classes of living and nonliving things (e.g., Golden retrievers are good hunting dogs; Firearms are the subject of great debate.)
- Characteristics of classes of events (e.g., The Super Bowl is the premier sporting event each year.)
- Characteristics of abstractions (e.g., Love is one of the most powerful human emotions.)

Principles

Principles are specific types of generalizations that deal with relationships. In general, there are two types of principles found in school-related declarative knowledge: *cause/effect principles* and *correlational principles*.

Cause/effect principles. Cause/effect principles articulate causal relationships. For example, the sentence, "Tuberculosis is caused by the tubercle bacillus" is a cause/effect principle. Although not stated here, understanding a cause/effect principle includes knowledge of the specific elements within the cause/effect system and the exact relationships those elements have to one another. That is, to understand the cause/effect principle regarding tuberculosis and the bacterium, one would have to understand the sequence of events that occur, the elements involved, and the type and strength of relationships between those elements. In short, understanding a cause/effect principle involves a great deal of information.

Correlational principles. Correlational principles describe relationships that are not necessarily causal in nature, but in which a change in one factor is associated with a change in another factor. For example, the following is a correlational principle: "The increase in lung cancer among women is directly proportional to the increase in the number of women who smoke." Again, to understand this principle, a student would have to know the specific details about this relationship. Specifically, a student would have to know the general pattern of this relationship, that is, the number of women who have lung cancer changes at the same rate as the number of women who smoke changes.

These two types of principles are sometimes confused with cause/effect *sequences*. A cause/effect sequence applies to a specific situation, whereas a principle applies to many situations. The causes of the Civil War taken together represent a cause/effect sequence. They apply to the Civil War only. However, the cause/effect principle linking tuberculosis and the tubercle bacillus can be applied to many different situations and many different people. Physicians use this principle to make judgments about a variety of situations and a variety of people. The key distinction between principles and cause/effect sequences is that principles can be exemplified in a number of situations, whereas cause/effect sequences cannot — they apply to a single situation only.

Concepts

Concepts are the most general way of thinking about knowledge in that virtually all ways of thinking about knowledge can be subsumed under them. That is, a concept can be the general category under which fall a number of principles and generalizations, a time sequence, a cause/effect sequence, an episode, and a number of vocabulary terms. Concepts are commonly represented by a single word or a phrase. For example, the word *dictatorship* can represent a concept. An important question here is, What is the difference between a vocabulary term and a concept inasmuch as both can be represented by a single word? For the most part, the difference lies in how the word is approached. If *dictatorship* were approached as a simple vocabulary term, students would be expected to have a general understanding of the term only — a general, but accurate, sense of what the word means. However, if the word were approached as a concept, students would be expected to know specific principles and generalizations about *dictatorships*, along with facts, episodes, and the like. At the level of concept, then, the word *dictatorship* would function as an organizer for all of the other types of declarative knowledge. Thus, concepts encompass much more information than the narrow range encompassed by a vocabulary term.

One final noteworthy difference between concepts and vocabulary terms is that all words can be addressed as vocabulary terms, but not all words can be addressed as concepts. Rather, only those words that represent broad categories of information qualify as concepts.

Figure 3.1. Type of Informational Knowledge.
(Note: Adapted from Marzano and Kendall, 1996, *A Comprehensive Guide to Designing Standards-Based Districts, Schools, and Classrooms)*

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Information and the Three Representational Modalities

Information is represented linguistically as declarative propositional networks. Recall from the discussion in Chapter 2 that declarative networks can be divided into semantic and episodic categories that consist of interrelated propositions. The different elements of the informational domain utilize different declarative structures. For example, facts, time sequences, temporal causal sequences, and episodes are primarily episodic in nature. Whereas vocabulary items, generalizations, principles, and concepts are primarily semantic in nature.

Informational knowledge commonly has a strong nonlinguistic representation. An individual's linguistic informational knowledge about automobiles will commonly be linked with images about cars, smells associated with cars, and kinesthetic sensations associated with cars.

Informational knowledge can have, but does not necessarily have strong affective representations unless dictated by the self-system. That is, if the self-system contains a belief that automobiles are dangerous, then all informational knowledge about automobiles will probably be linked to a strong primary emotion of fear.

The Mental Process Domain

Like the informational domain within a subject area, knowledge within the mental process domain can be organized as a hierarchy. At the top of the hierarchy are highly robust processes that have a diversity of possible products or outcomes and involve the execution of many interrelated subprocesses. Robust processes that have these characteristics are referred to as *macro-processes* (Marzano and Kendall, 1996). For example, the process of effectively using laboratory equipment in a science class fulfills the defining characteristics of a macro-process. Different students will no doubt come to different conclusions as a result of using the lab equipment; additionally, a number of subprocesses will be employed while utilizing the lab equipment. To perform this macro-process, an individual will need to execute a subprocess for sequencing the use of specific equipment, sequencing the dismantling of equipment, and so on.

Somewhat in the middle of the hierarchy are processes that do not generate the variety of products possible from processes and do not incorporate the wide variety of subprocesses that macro-processes do. These processes are commonly referred to as *tactics*. For example, an individual may have a tactic for reading a histogram. Commonly, tactics do not consist of a set of steps that must be performed in a specific order. Rather, they are made up of general rules with an overall flow of execution. For example, a tactic for reading a histogram might include rules that address: (1) identifying the elements depicted in the legend, (2) determining what is reported in each axis on the graph, and (3) determining the relationship between the elements on the two axes. Although there is a general pattern in which these rules are executed, there is no rigid or set order.

Algorithms are even more specific types of processes than tactics. These processes normally do not vary in application, they have very specific outcomes, and frequently they must be learned to the level of automaticity to be useful. For example, many computing processes in mathematics and decoding processes in reading are algorithmic in nature.

The simplest type of process is a *single rule* or a small set of rules with no accompanying steps. In the terms articulated in Chapter 2, a single rule would consist of one IF/THEN production — IF situation X occurs, THEN perform action Y. Single rule processes are not very common, since rules are commonly employed as a group with some general pattern of execution. As we have seen, in such cases the set of rules with the accompanying general pattern of execution is referred to as a tactic. However, there are occasions when a single rule or small set of rules is executed. For example, a student who knows five rules for capitalization might apply these independently while editing her writing. In such a situation, the student would be utilizing a group of single rule procedures. If the student systematically executed the rules in a set sequence, however, (e.g., check capitalization at the beginning of each sentence first, next check the capitalization of proper nouns, and so on) the student would have organized the single rule procedures into a tactic or algorithm, depending on how rigidly she followed the pattern of execution.

Mental Processes and the Three Representational Modalities

By definition, mental processes are fundamentally procedural in nature. They are made up of interacting sets of IF/THEN structures (i.e., productions) that are, by definition, linguistic in nature. Mental process knowledge also includes declarative networks. To illustrate, consider the knowledge necessary to set up and utilize laboratory equipment. The steps involved would be represented as IF/THEN productions. However, in addition to the procedural networks, the individual's knowledge of this mental process would also include some information (i.e., declarative networks), such as an understanding of the various parts of a specific piece of equipment and how they interact.

Mental process knowledge, like informational knowledge, can have a strong nonlinguistic representation that employs images to a great extent. Specifically, research indicates that a mental process progresses through a series of stages while it is being learned (Anderson, 1983; Fitts, 1964; Fitts and Posner, 1967). It is during the initial stage of acquiring a mental skill that the learner creates a representation of the process. By definition, this representation will include a linguistic component in the form of IF/THEN productions. Additionally, the learner will commonly form images of the steps involved. For example, when first learning the process involved in using laboratory equipment in a science class, a student might form mental images of the actual steps that are involved.

As is the case with knowledge in the informational domain, there is no necessary affective representation associated with mental process knowledge unless the individual has a strong negative or positive association with the process. For example, an individual might have a strong affective representation associated with the process of utilizing laboratory equipment because of an accident the individual once experienced while utilizing the process. In this case, the emotion associated with the process knowledge might be fear.

The Psychomotor Domain

The psychomotor domain includes the physical skills and abilities an individual utilizes to negotiate daily life and engage in complex physical activities for work and for recreation. It should be noted that Bloom and his colleagues (Bloom et al., 1956) originally intended to address psychomotor skills as a separate domain.

Here, psychomotor skills are considered a part of the knowledge domain for a number of reasons. First, most psychomotor skills and processes are stored in memory in a fashion identical to strict mental processes. Specifically, they are stored as procedural networks with an IF/THEN syntax (Anderson, 1983). Secondly, the stages of development for learning psychomotor skills are similar, if not identical, to those involved in learning mental skills (Anderson, 1983, 1995; Gagne, 1977, 1989).

As is the case with the other two domains, the elements of the psychomotor domain can be organized into a hierarchy. At the bottom of the psychomotor hierarchy are foundational physical skills upon which more complex skills are developed. Carroll (1993) has identified a number of foundational skills that include:

- static strength
- overall body equilibrium
- speed of limb movement
- wrist-finger speed
- finger dexterity
- manual dexterity
- arm-hand steadiness
- control precision

It is clear from the listing that most of these skills are developed without formal instruction. Indeed, human beings perform all of these physical functions quite naturally with a certain degree of acumen. However, this is not to say that these foundational skills cannot be improved with instruction and practice. For example, with instruction, a person can improve his manual dexterity.

A level up from basic foundational skills are simple combination skills such as aiming. As their name implies, simple combination skills involve sets of foundational skills acting in tandem. For example, aiming is an example of a simple combination skill that involves the interaction of a number of foundational skills including wrist-finger speed, control precision, and arm-hand steadiness.

Finally, complex combination skills utilize sets of simple combination skills. For example, the act of shooting a jump shot in basketball would involve the combination skills of aiming, along with other combination skills like jumping to set up a jump shot, placing the ball in a position where it cannot be blocked, and so on. What is commonly thought of as a "sport," then, or a "recreational" activity can be operationally defined as the use of a set of complex combination skills for the purpose of accomplishing specific physical goals (e.g., hitting a ball over a net within prescribed boundaries using a specific type of racquet).

Psychomotor Domain and the Three Representational Modalities

Above the level of foundational physical skills, the skills within the psychomotor domain have a strong linguistic representation in that they are stored as productions (IF/THEN propositions). This is most likely not the case for foundational skills which are probably best described as reflexive in nature. That is, foundational skills are "hard-wired" aspects of human physiology. However, when these foundational skills are combined to form simple or complex combination skills, they must be learned much as an individual learns a mental skill. As described previously, in the first stages of learning, an individual stores the various steps to the skill as linguistically based IF/THEN propositions.

Psychomotor knowledge also has a strong nonlinguistic representation. Indeed, the primary representational modality for psychomotor knowledge is kinesthetic or "muscle memory." Additionally, in the early stages of psychomotor learning, skills might also be represented as mental images. In fact, imagining the steps involved in a psychomotor skill is one form of practice for such skills (Richardson, 1983). Finally, psychomotor skills do not necessarily have an affective component unless they are associated with highly positive or negative events.

The Cognitive System

The processes within the cognitive system can be organized into four categories: (1) storage and retrieval, (2) information processing, (3) input/output, and (4) knowledge utilization. These mental processes act on the knowledge in the knowledge domains. That is, the storage and retrieval processes provide an individual with access to the knowledge that has been stored in permanent memory and a way of storing new knowledge so that it might be used at a later date. The information processing functions manipulate knowledge that has been stored so that it might be utilized for specific tasks. The input/output processes utilize knowledge to understand communication and generate communications. Finally, the knowledge utilization processes use knowledge to accomplish specific tasks. Each category of processes within the cognitive system is discussed below.

Storage and Retrieval

As their name implies, the function of the storage and retrieval processes is to embed (i.e., store) data in permanent memory and to extract (i.e., retrieve) data from permanent memory so that it might be used. To better understand the functioning of the storage and retrieval processes, it is useful to consider briefly the nature and function of memory.

Anderson (1995) explains that the long held conception of two types of memory — short-term and long-term — has been replaced with the theory that there is only one type of memory with different functions. For the purpose of this discussion, we consider three functions: sensory memory, permanent memory, and working memory.

Sensory memory deals with the temporary storage of data from the senses. Anderson describes sensory memory in the following way:

> Sensory memory is capable of storing more or less complete records of what has been encountered for brief periods of time during which people can note relationships among the elements and encode the elements in a more permanent memory. If the information in sensory memory is not encoded in the brief time before it decays, it is lost. What subjects encode depends on what they are paying attention to. The environment typically offers much more information at one time than we can attend to and encode. Therefore, much of what enters our sensory system results in no permanent record. (1995, p. 160)

Permanent memory contains all information and skills that constitute the domains of knowledge and the cognitive, metacognitive, and self-systems. In short, all that we understand and know how to do is stored in permanent memory.

Working memory utilizes data from both sensory memory, and from permanent memory. As its name implies, working memory is where data is actively processed. To this extent, it is the venue in which consciousness occurs (Dennett, 1969, 1991). Anderson explains that within psychology there has been some discussion about extending the concept of working memory to include information "outside of the boundaries of the organism." For example, when a person solves a complex mathematical problem, the information available to the problem solver includes not only what the problem solver has in working memory, but also information on the page like equations and mathematical expressions. As intriguing as this concept is, Anderson notes that it ultimately becomes problematic.

> Some people extend the concept of working memory to the external environment. The problem with doing so is that it is unclear where to stop. If the information on a page of a text, on the computer screen, and on the kitchen counter is in working memory because it can be accessed with a change of glance, what about the information on the next page, or in a computer file, or in the kitchen cupboard, all of which can be accessed with only a little more effort. (1995, p. 182)

Relative to the theory presented in this book, working memory is considered the forum in which information from the outside world or from permanent memory is processed. The relationship between the outside world, sensory memory, working memory, and permanent memory is depicted in Figure 3.2.

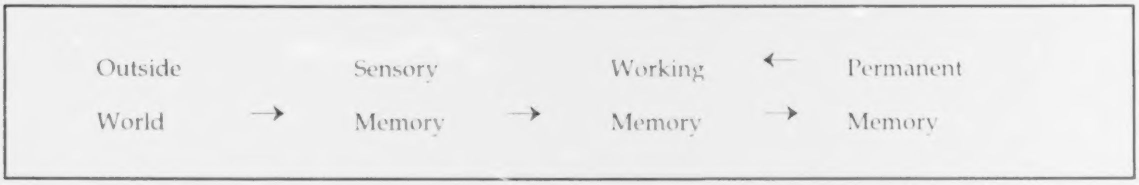

Figure 3.2. Types of Memory.

As depicted in Figure 3.2, working memory can receive data from both sensory memory (where it is held only briefly) and from permanent memory (where it resides permanently) or from both. There is no theoretical limit on the amount of time data can reside in working memory. As long as an individual focuses consciousness on the data in working memory, it stays active.

Anderson (1995) explains that working memory contains two processes that allow information to stay active in working memory. These functions are the phonological loop and the visio-spatial sketch pad. Stated differently, the phonological loop and the visio-spatial sketch pad allow individuals to hold information in working memory after it has decayed in sensory memory. Specifically, when first perceived, both visual and auditory memory are stored in sensory memory where they last little more than a second (Anderson, 1995). The phonological loop and the visio-spatial sketch pad are mechanisms by which this data is rehearsed and held active in working memory.

With a basic understanding of the construct of working memory, retrieval can be described as the activation and transfer of data from permanent memory into working memory where they might be consciously processed. Storage can be described as the encoding (via the three representational systems) of data already in working memory in such a way that they becomes part of permanent memory. In his synthesis of factor analytic studies conducted in psychology, Carroll (1993) found that the ability to hold both auditory and visual stimuli were salient abilities in the research on general cognitive functionings as were the processes of retrieval and storage.

Storage and retrieval are, of course, innate processes — they are part of every human's neurological "hard wiring" and are therefore not learned. This is not to say, however, that they cannot be enhanced via the use of learned tactics, such as mnemonics to enhance storage and priming to enhance retrieval.

The Information Processing Functions

The information processing functions "act on" the data residing in working memory. This is depicted in Figure 3.3.

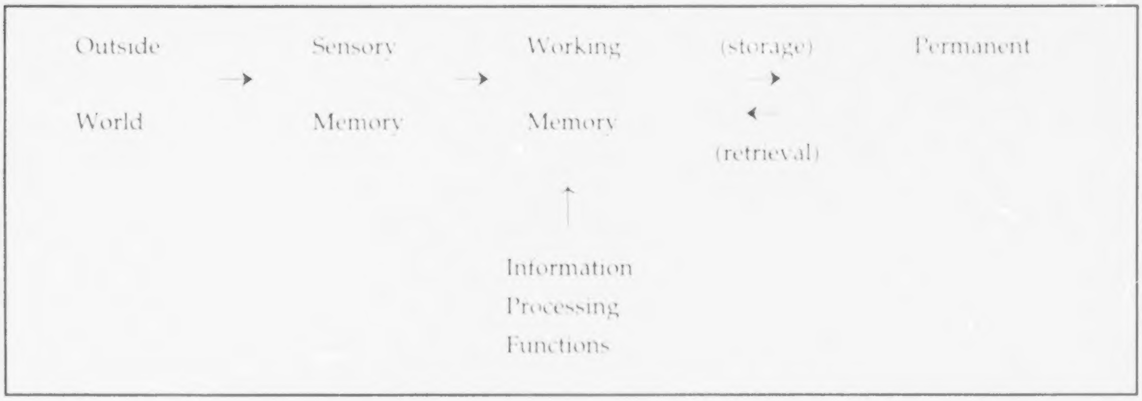

Figure 3.3. Information Processing Functions.

As Figure 3.3 indicates, the information processing functions operate in the data in working memory regardless of whether that data originates from the outside world via the sensory memory or from permanent memory via retrieval.

There are six basic information processing functions: (1) matching (2) idea representation, (3) information screening, (4) generalizing, (5) specifying, and (6) idea production.

Matching. Matching processes address the identification of similarities and differences for the elements in working memory. This is perhaps the most basic of all aspects of information processing (Smith and Medin, 1981). That is, matching is fundamental to most, if not all other types of information processing functions. Matching is the basic process that allows us to organize our experiences into categories. As Mervis (1980) notes, the world is composed of an infinite number of stimuli. People make the unfamiliar familiar by organizing the myriad of stimuli that bombard their senses into like categories. Indeed, Nickerson, Perkins and Smith (1985) note that the ability to form categories of like stimuli is central to all forms of thought.

Researcher Arthur Markman and his colleagues have determined that of the two aspects of matching, identifying similarities is the more primary, since without the identification of similarities, no differences can be discerned (Markman and Gentner, 1993a, 1993b; Medin, Goldstone and Markman, 1995; Gentner and Markman, 1994).

Idea Representation. Idea representation is the process of translating the data in working memory into a form suitable for storage in permanent memory. The data in working memory are not exact copies of those perceived through the senses. As explained earlier, the data in sensory memory fade quite quickly. To a great extent, then, working memory contains constructed representations, which are always interpretations of sensory data. Holland, et al. (1986) explain that working memory contains "models" of the outside perceived through the senses. In effect, then, the idea representation function is charged with the task of designing the models of the outside world. As described in Chapter 2, these models can have linguistic, nonlinguistic, and affective components.

A point of clarification is useful here relative to the differences between the idea representation function and the three processors described in Chapter 2. The idea representation function coordinates the activity of the linguistic, nonlinguistic, and affective processors. While these processes are automatic, mechanistic, and unconscious, the idea representation function directs the use of these processors. Specifically, the idea representation function determines if data received from the senses should be represented in all three modalities or have a primary form of representation. To illustrate, two individuals listening to the same description of an event might represent that event quite differently in working memory. One individual might utilize a representation that is highly linguistic in nature, while the other might utilize a representation that is highly nonlinguistic. It is the selection (sometimes at a conscious level) of the exact nature of the model of the world within working memory that is the product of the idea representation function. Some theorists assert that one's propensity to use one representational modality over another constitutes the individual's style of information processing (Carbo, Dunn and Dunn, 1986; McCarthy, 1980).

Information Screening. The information screening functions address the logic or reasonableness of data that have been represented in working memory. The existence of this function implies that information must be considered reasonable for an individual to accept it as valid (Gilovich, 1991). To illustrate, assume that an individual is engaged in reading an article on a given topic. As the incoming information is being represented in working memory in linguistic, nonlinguistic, and possibly affective forms, the individual screens the new knowledge to determine if it makes sense relative to what the student already knows about the topic. If the information is considered illogical or unreasonable relative to what the individual already knows about the topic, then it would be tagged as such prior to being stored in permanent memory or totally rejected.

In his synthesis of factor analytic studies, Carroll (1993) refers to this basic function as "reasoning." Philosophers such as Paul (1990), Ennis (1985), and Lipman (Lipman, Sharp and Oscanyan, 1980) have stressed the importance of this general screening process to every day functioning.

Information Generalization. The information generalization function generates inferences about specific information in working memory regarding their relationships to more general structures. These inferences are generally considered to be highly inductive in nature. Holland and his colleagues (Holland, Holyoak, Nisbett and Thagard, 1986) describe inductive inferences in great depth noting that their end product is new rules and principles that are then stored in permanent memory. To illustrate, again assume that an individual is engaged in reading an article on a given topic. While reading the article, working memory would contain a number of propositions about the topic. The information generalization function would translate these propositions into generalizations and principles about the topic.

Holland et al. (1986) postulate four types of rules that are the working parts of the induction process. *Specialization rules* state that if a previously generated rule does not provide accurate guidance in a specific situation, then a more specific rule should be generated. *Unusualness rules* state that if a situation has an unexpected property relative to the rule that governs the situation, a conditioned element should be added to the original rule. The *rule of large numbers* states that when generating a rule based on a sample of events or elements, the rule should be generated under the assumption that it applies to all elements in the set; however, a strength parameter should be attached to the rule proportionate with the number of events or elements that have been sampled — the more events or elements, the greater the strength of the rule. *Regulation rules* state that if an individual has a rule of the following form: "If you want to do X, then you must first do Y," then a rule like the following should be generated: "If you do not do Y, then you cannot do X" (p. 42). It should be noted that information generalization via induction is also the basis of analogy and metaphor. Once similarities and differences have been identified via matching processes, linkages are made to more general structures to form analogies and metaphors (Ortony, 1980).

Information Specification. Where the information generalization function is inductive in nature, the information specification function is more deductive. Holland et al. (1986) explain that deductions (i.e., specifications) are made via two types of rules: synchronic and diachronic. Synchronic rules are atemporal in nature and form the basis for classification and categorization. There are two types of synchronic rules: categorical and association. These are exemplified below.

1. Categorical
   If an object is a dog, then it is an animal.
   If an object is a large slender dog with very long white and gold hair, then it is a collie.

2. Associative
   If an object is a dog, then activate the "cat" concept.
   If an object is a dog, then activate the "bone" concept.

Diachronic rules deal with basic relationships of cause/effect, and temporal order. There are two types of diachronic rules: predictor and effector. These are exemplified below.

1) Predictor
   If a person annoys a dog, then the dog will growl.
   If a person whistles to a dog, then the dog will come to the person.

2) Effector
   If a dog chases you, then run away.
   If a dog approaches you with a wagging tail, then pet it.

Based on his review of the factor analytic studies that have been conducted in psychology, Carroll (1993) also includes rules for ordering as a critical type of deduction.

Highly specific sets of logic rules have been proposed by some psychologists (see Braine, 1978) as the basis for deduction. These rules are sometimes referred to as a form of "mental logic." Johnson-Laird (1983; Johnson-Laird and Byrne, 1991) has challenged the rule-based theory of deduction in favor of one that assumes that nonlinguistic "tokens" are used to generate deductions.

Idea Production. The idea production function generates new propositions using information from permanent memory. In his review of factor analytic studies, Carroll (1993) has referred to this process as "expressional fluency." This function is always used when an individual is in the process of communicating in oral or written form. For example, during the writing process, the writer constructs ideas that will be translated into written language. Bereiter and his colleagues (Bereiter, Fine and Gartshore, 1979; Bereiter and Scardamalia, 1982, 1985) refer to these ideas as "gist units"; Hillocks (1987) describes these prelinguistic ideas as "a generally circumscribed unit of content that has not been laid out in any detail, but for which the writer probably has notions of form and purpose" (p. 73).

The idea production is also used in situations that are not communication oriented. For example, an individual sitting alone will produce new ideas that might not ever be communicated to anyone else. The newly constructed ideas are commonly manifested as inner speech — a dialogue with oneself.

Basic Input/Output Communication Processes

Where the information processing functions deal primarily with the immediate data in working memory, input/output communication processes address transactions with the outside world — communicating information to the outside world and taking in communication from the outside world. By definition, all of these processes utilize the storage and retrieval processes as well as the information processing functions. This is depicted in Figure 3.4.

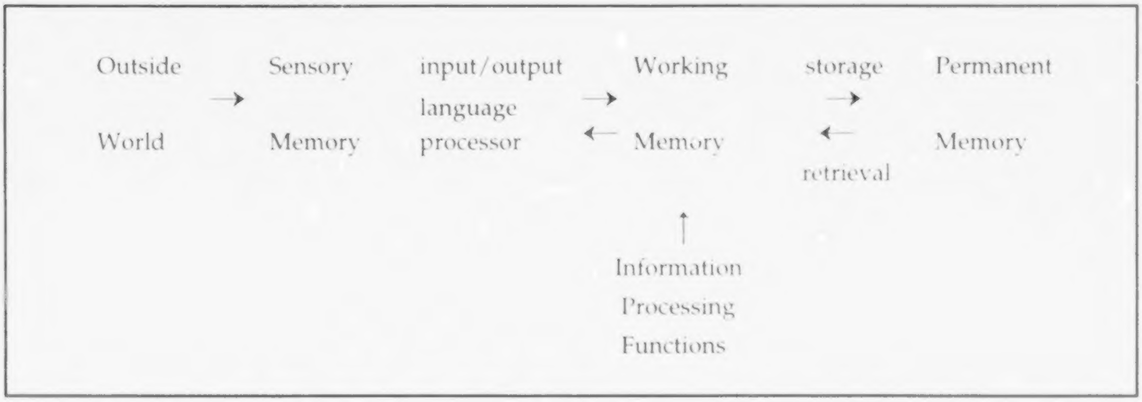

Figure 3.4. Basic Input/Output Communication Processes.

Figure 3.4 illustrates that the basic input/output communication functions utilize a language processor specific to these functions. This processor is responsible for decoding language from the outside world and encoding thoughts generated in working memory into a surface-level linguistic form suitable for communication with the outside world. It is important to note that the discussion of input/output processes here is limited to communication in linguistic form. That is, the discussion does not include input functions such as viewing or output functions such as nonverbal communications. The input communication processes are listening and reading.

Listening. Figure 3.4 illustrated that the input/output functions require the use of a language processor. This language processor employs different functions depending on the type of communication. Listening (as does reading) requires the utilization of an oral language decoding function. This is depicted in Figure 3.5.

It is important here to distinguish between the oral language decoding functions used during listening and the linguistic processor discussed in Chapter 2. The linguistic processor translates data in working memory into abstract propositions. As described in Chapter 2, these propositions are in an abstract, deep-structure format that will be the same from individual to individual regardless of the language they use. The task of the oral language decoder depicted in Figure 3.5 is to translate spoken language into recognizable language patterns — surface-level language. That is, when listening to speech, an individual must decode the sounds emitted by the speaker into recognizable words, phrases, and sentences in the target language.

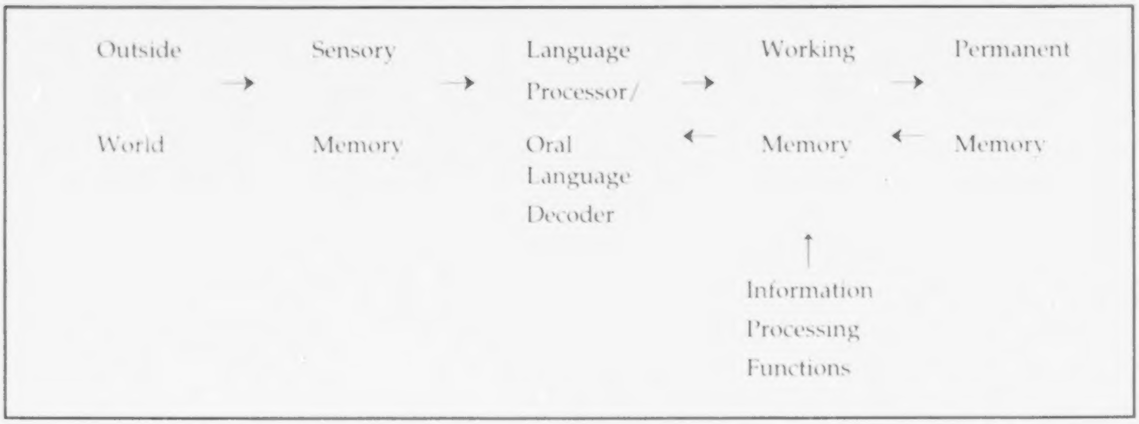
Outside World
Sensory Memory
Language Processor/ Oral Language Decoder
Working Memory
Permanent Memory
Information Processing Functions

Figure 3.5. The Listening Process.

The process of translating sounds into recognizable words is not as straightforward as it might seem. Specifically, the sounds produced by a speaker do not physically conform to the words of the speaker's language (Adams, 1990; Fredericksen, 1978, 1982). Rather, individual words are sometimes indistinguishable from one another in terms of the physical junctures between the actual sounds produced. In fact, it is the listener's understanding of the target language that allows him to translate the physical sound produced by the speaker into actual words from the target language. Recognizing words, then, is an interpretive process — at least to some extent. Once sounds are recognized as words, the oral language decoder is free to organize the words into proper syntactic and semantic elements. In summary, the oral language decoder translates the sound waves emitted by a speaker into surface-level language with appropriate phonemic, syntactic, and semantic features. It is this surface-level language that is deposited in working memory where it is rehearsed (via the phonological loop) and analyzed via the information processing functions.

In addition to the oral language decoder, the listening process requires the execution of an overall process that involves specific steps or heuristics. For example, while listening in the context of an informal conversation, the listener will follow certain conventions such as signaling her understanding of what is being said by a nod of the head or some other physical gesture. The steps or heuristics involved in listening within a more formal context might be quite different (Clark and Clark, 1977).

Finally, the process of listening requires the retrieval of information about the topic. That is, the listener activates what she already knows about the topic and utilizes this prior knowledge to help her interpret what the speaker is saying.

In summary, the process of listening is a complex task involving the following activities and their related functions:

1. The decoding of oral language, via the oral language decoder, into recognizable words, phrases, and sentences
2. The analysis of the data in working memory via the information processing functions
3. The activation, via the retrieval function, of prior knowledge relative to the topic of the conversation or presentation
4. The activation, via the retrieval function, of knowledge about the overall process of listening

Reading. The input process of reading is quite similar to the input process of listening except that it requires the use of a written language decoder as opposed to an oral language decoder. This is depicted in Figure 3.6.

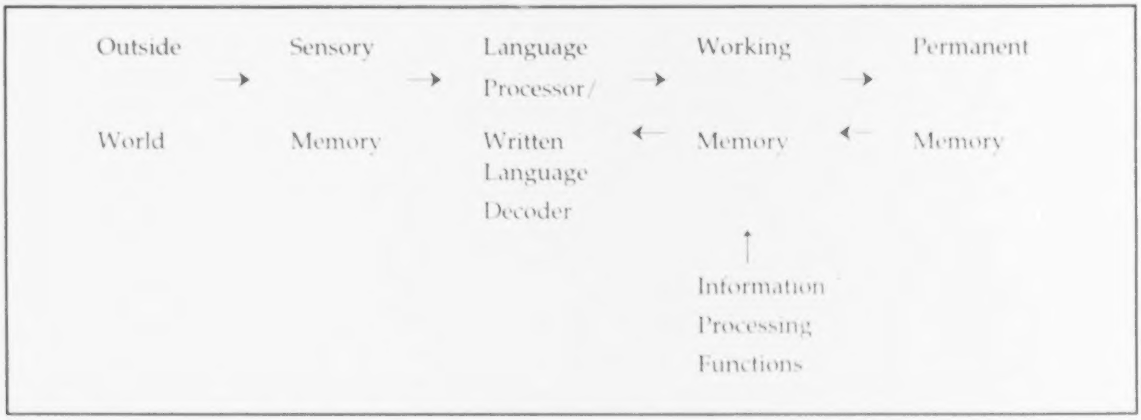
Outside World
Sensory Memory
Language Processor/ Written Language Decoder
Working Memory
Permanent Memory
Information Processing Functions

Figure 3.6. The Reading Process.

The written language decoder performs the same basic function as the oral language decoder except that its initial task is to translate orthography (i.e., print) to recognizable words. A strong case can be made for the assertion that the reader translates the printed words into their phonological equivalents before translating them to words (Adams, 1990). The decoding process, then, progresses from print to sound and then to recognizable words. Once this translation occurs, the written language decoder constructs a surface-level representation of the syntactic and semantic aspects of the written message first, as the oral language decoder does. It is this surface-level language that is deposited in working memory, where it is analyzed by the information processing functions.

As is the case with the listening process, the reading process involves the execution of an overall process or set of heuristics that governs the flow of processing. Jones and her colleagues (Jones, 1985; Jones, Amiran and Katims, 1985; Jones, Friedman, Tinzmann and Cox, 1984; Palincsar, Ogle, Jones and Carr, 1986) have characterized this overall process as involving three phases: before reading, during reading, and after reading. Within the "during reading" phase of the process, the reader is engaged with actual text. Thus, the written language decoder would be employed. However, within the "before" and "after reading" phases of the process, the reader would be interacting with his or her stored and newly acquired knowledge about the topic. The written language decoder would not be employed during these phases.

Finally, the reading process requires retrieval of information about the topic and about the format of the written discourse that has been employed. As is the case with listening, the more the reader knows about the topic, the more efficient will be his reading. Consequently, as part of the reading process, the reader retrieves what he already knows about the topic. Unlike the listening process, reading also requires the retrieval of information about the type of discourse that is being read. For example, to read and understand a technical article, one must not only understand the meaning of the words, phrases, and sentences that are being used, but also the conventions specific to technical articles such as the meaning of various types of headings, abbreviations, and so on.

In summary, the process of reading is a complex task involving the following activities and their related functions:

1. The decoding of written language, via the written language decoder, into recognizable words, phrases, and sentences

2. The analysis of the data in working memory via the information processing function

3. The activation, via the retrieval function, of prior knowledge about the topic

4. The activation, via the retrieval function, of prior knowledge about the type of discourse in which the message is presented

5. The activation, via the retrieval function, of knowledge about the overall process of reading

Speaking. Speaking is a basic output communication function that is analogous to listening in that it utilizes spoken language. The speaking process is depicted in Figure 3.7.

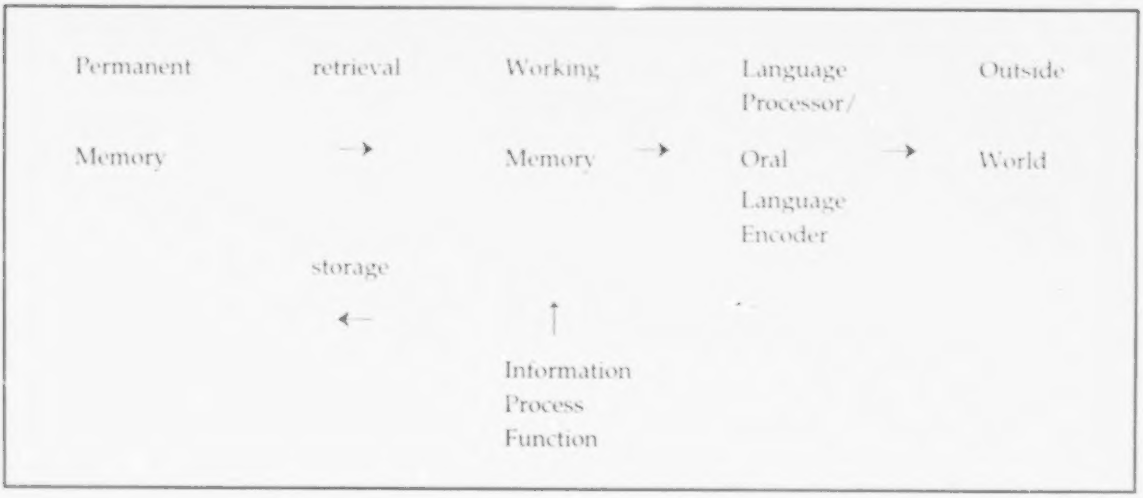
Permanent Memory
retrieval
storage
Working Memory
Language Processor/ Oral Language Encoder
Outside World
Information Process Function

Figure 3.7. The Speaking Process.

Note that Figure 3.7 depicts the flow of data as progressing from permanent memory to the outside world as opposed to the outside world to permanent memory, as is the case with Figure 3.5 (listening) and 3.6 (reading). This is because speaking is an output communication process, whereas listening and reading are input processes. When engaged in speaking, an individual attempts to communicate information she possesses in permanent memory to the outside world.

Another significant difference between the process of speaking and those of listening and reading is that speaking requires a language *encoding* mechanism, whereas listening and reading require a language *decoding* mechanism. The difference between the language encoding mechanism and the language decoding mechanism is most easily understood if considered after a discussion of the aspects of speaking that precede it.

The process of speaking most probably begins with the speaker's retrieval of information from permanent memory about the topic. The more he knows about a topic, the easier it is to speak about it. The prior knowledge of the topic is deposited in working memory. The speaker also retrieves from permanent memory knowledge about the conventions to follow in the overall process of speaking. The conventions that would be used in an informal conversation would be quite different from those used in a formal speech (Clark and Clark, 1977).

The information about the topic that has been deposited in working memory is acted upon by the information processing function. Of these, one of the most critical to the speaking process is the idea production function, which translates the data in working memory into thoughts that will be translated into surface-level language. As described previously, these thoughts have been described as "content that has not been described in detail" (Hillocks, 1987).

Once ideas have been generated, the language encoder translates them into surface-level language. This process includes: identifying the specific words that will be used, determining the correct pronunciation of these words, and designing the syntax that will be used to express the thoughts. In his synthesis of the factor analytic studies of cognition, Carroll (1993) found evidence for all of these aspects of the language encoding mechanism. The specific factors found by Carroll that relate to the speaking process are ideational fluency, name facility, associative fluency, expressive fluency, and word fluency.

Like listening and reading, speaking is a complex task that involves the following activities and their related functions.

1. The activation, via the retrieval function, of prior knowledge about the topic

2. The activation, via the retrieval function, of knowledge about the overall process of speaking

3. The analysis of data in working memory via the information processing functions

4. The encoding of the ideas generated in working memory into surface-level language via the oral language encoder

Writing. As speaking is analogous to listening, writing is analogous to reading. Listening and speaking both utilize oral language; reading and writing both utilize written language. The components involved in the writing process are depicted in Figure 3.8.

Again, the flow of processing in writing is from permanent memory to the outside world as the writer attempts to communicate information he possesses. As is the case with speaking, the writing process begins with the writer retrieving information from permanent memory about the topic. Again, the more one knows about a topic, the easier it is to write about it. Additionally, the writer must retrieve her knowledge of the type of discourse that will be the medium of communication. Specifically, the writer must consider and utilize the various conventions of the medium in which she is communicating. For example, the conventions used to write a letter are different from the conventions used to write a research report, which are different from the conventions used to write a story. The final type of knowledge that must be retrieved from permanent memory is that about the overall process of writing. Flower and Hayes (1980a, 1980b, 1981a, 1981b) have characterized the process as involving three interactive phases: planning, translating, and reviewing.

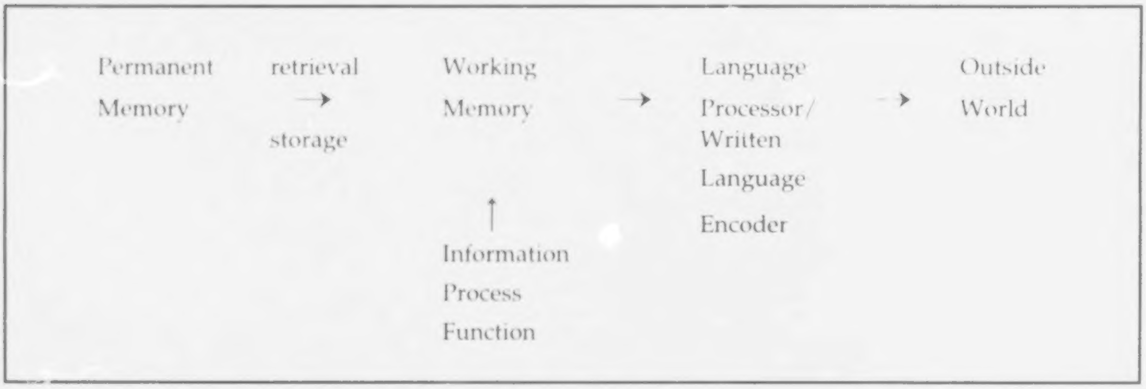
Permanent Memory
retrieval
storage
Working Memory
Information Process Function
Language Processor/ Written Language Encoder
Outside World

Figure 3.8. The Writing Process.

Once information about the topic has been deposited in working memory, it is acted upon by the basic information processor functions. As is the case with speaking, the most important of these functions is idea generation, which is responsible for generating the ideas that will be translated to surface-level language. It is the task of the written language encoder to translate the thoughts in working memory into surface-level language. As is the case with the oral language encoder, the written language encoder selects the words that will be used to express the thoughts produced by the idea generator along with the syntax in which those words will be expressed. However, where the oral language encoder determines the correct pronunciation of the words that have been selected, the written language encoder identifies the correct orthographic form of the word (i.e., the correct spelling or physical representation of the word).

Again, like listening, reading, and speaking, writing is a highly complex process that involves a number of components.

1. The activation, via the retrieval function, of prior knowledge about the topic

2. The activation, via the retrieval process, of knowledge about the type of discourse to be used

3. The activation, via the retrieval process, of knowledge about the overall writing process

4. The analysis of data in working memory via information processing functions

5. The encoding of idea generation in working memory into surface-level language via the written language encoder

The Hybrid Nature of the Input/Output Communication Functions

From the discussion above, it is clear that the input/output communication functions are not singular functions within the cognitive system. Rather, they are hybrid processes involving a number of related functions within the cognitive system. For example, all input/output communication functions make heavy use of the storage and retrieval functions, as well as the basic information processing functions. Thus, one might say that they are "second order" cognitive processes in that they are composed of combinations of more basic cognitive functions.

There are, however, a few unique aspects of the input/output communication functions. These include the use of the language decoding mechanisms (for listening and reading), and the language encoding mechanism (for speaking and writing). In addition, each input/output process has an overall process or set of heuristics associated with it. As shall be discussed in a subsequent section, the control of this overall process is commonly under the control of the metacognitive system.

Knowledge Utilization Processes

There are four knowledge utilization processes: (1) decision-making, (2) problem-solving, (3) experimental inquiry, and (4) investigation.

Decision-making. The process of decision-making is utilized when an individual must select between two or more alternatives (Baron, 1982, 1985; Halpern, 1984). The execution of the decision-making process requires an individual to retrieve from permanent memory his prior knowledge about the topic. For example, if the individual is going to make a decision regarding where to go on a Sunday afternoon pleasure drive, he will retrieve what he knows about local destinations. He will also retrieve what he knows about the various steps and heuristics involved in the overall process of decision-making. Steps and heuristics commonly associated with the overall process of decision-making include:

- identification of alternatives
- assigning of values to alternatives
- determination of probability of success
- determination of alternatives with highest value and highest probability of success

(Baron, 1985; Wales and Stager, 1977)

The execution of each of these steps requires the individual to analyze the data in working memory using the basic information processing functions. For example, to assign value to alternatives, an individual must use the matching function to determine the similarities and differences between the characteristics of the alternatives that have been identified and the characteristics of a "successful Sunday drive" as defined by the individual.

In summary, decision-making involves the following aspects:

1. Activation, via retrieval of knowledge about the topic — the alternatives under consideration and personal values related to those alternatives

2. Activation, via the retrieval function, of knowledge about the overall process involved in decision-making

3. Analysis of data in working memory via the information processing functions

Problem-solving. The process of problem-solving is utilized when an individual is attempting to accomplish a goal for which an obstacle exists (Rowe, 1985). As is the case with decision-making, problem-solving requires the activation of prior knowledge about the topic. For example, if an individual wishes to be at a specific location some miles from her home by a certain time and her car breaks down, she has a problem — she is attempting to accomplish a goal (i.e., to transport herself to a specific location) and an obstacle has arisen (i.e., her usual mode of transportation is not available). To address this problem effectively, the individual would have to retrieve from permanent memory her prior knowledge about different methods of transportation that are alternatives to taking her car (e.g., taking the bus, calling a friend) as well as options for fixing her car within the available time.

In addition to knowledge about the topic, the individual would have to retrieve her knowledge about the overall process of problem-solving. Steps and heuristics commonly associated with problem-solving include:

- identification of obstacle to goal
- possible re-analysis of goal
- identification of alternatives
- evaluation of alternatives
- selection and execution of alternatives

(Halpern, 1984; Rowe, 1985; Sternberg, 1987)

Again, the execution of each of these steps or heuristics requires the individual to analyze the data in working memory using the information processing functions. Of these functions, information specification and information screening are probably key factors. An individual uses the specifier to generate hypotheses about possible ways to overcome the obstacle. The information screener is used to evaluate the feasibility and likelihood of the options that have been generated. In summary, problem-solving involves the following components:

1. Activation via retrieval of knowledge about the topic

2. Activation via retrieval of knowledge about the overall process involved in problem-solving process

3. Analysis of data in working memory via the information processing function

Experimental inquiry. Experimental Inquiry involves generating and testing hypotheses for the purpose of understanding some physical or psychological phenomenon. To engage in experimental inquiry, an individual must activate knowledge of the topic. For example, if an individual has a question about how airplanes fly, she will activate her knowledge of concepts important to the phenomenon under investigation such as *lift* and *drag*. Additionally, she will retrieve from permanent memory knowledge of the steps and heuristics involved in the process of experimental inquiry. The steps and heuristics commonly associated with the experimental hypothesis include:

- making predictions based on known or hypothesized principles
- designing a way to test the predictions
- evaluating the validity of the principles based on the outcome of the test

(Halpern, 1984; Ross, 1988)

The execution of these steps requires the individual to analyze the data in working memory using the information processing function. Of these functions, information specification and information screening are probably key. For example, the information specification function would be used to generate predictions based on known principles about lift and drag. The information screening function would be used to judge the reasonableness of the results of the experiment given the individual's initial understanding of the concepts of lift and drag.

In summary, the experimental inquiry process involves the following components:

1. Activation via retrieval of knowledge about the topic under investigation

2. Activation via retrieval of knowledge about the overall process involved in experimental inquiry

3. Analysis of data in working memory via the information processing function

Investigation. Investigation is the process of generating and testing hypotheses about past, present, or future events. It is similar to experimental inquiry in that hypotheses are generated and tested. It differs from experimental inquiry in that it utilizes different "rules of evidence." Specifically, the rules of evidence for investigation adhere to the criteria for sound argumentation like the establishment of warrants (Toulmin, 1958; Toulmin, Rieke and Janik, 1981), whereas the "rules of evidence" for experimental inquiry adhere to the criteria for statistical hypotheses testing.

In short, the investigation process can be conceptualized in the same way as the experimental inquiry process:

1. Activation via retrieval of knowledge about the topic
2. Activation via retrieval of knowledge about the overall process involved in investigation
3. Analysis of data in working memory via the information processing function

From the discussion above, it should be clear that all the knowledge utilization processes have the same basic syntax. Specifically, they require individuals to retrieve knowledge of the topic from permanent memory as well as knowledge of the overall process involved. Additionally, they all make heavy use of the information processing functions to analyze the data in working memory throughout the execution of the overall process. The primary difference in the knowledge utilization processes is in the steps and heuristics that define the overall process and the information processing functions they most heavily employ.

The Hybrid Nature of the Knowledge Utilization Process

As is the case with the input/output communication process, the knowledge utilization processes are hybrid processes in that, to a great extent, they consist of sets of storage and retrieval and information processing functions. Indeed, one might make the case that the cognitive system is comprised of four categories of functions: (1) storage and retrieval process, (2) basic information processing function, (3) a language decoding mechanism (oral and written), and (4) a language encoding mechanism (oral and written). All other processes (e.g., reading, writing, listening, speaking, problem-solving, decision-making, experimental inquiry, and investigation) are characterized by patterns of use of these four types of processes. The only thing unique to these second-order processes is the particular issue they address and the general flow of processing (i.e., the overall process involved). However, given that the input/output communication processes and the knowledge utilization processes are commonly thought of as being cognitive processes and have a substantial number of instructional strategies dedicated to them, they will be considered aspects of the cognitive system within this model.

The Cognitive System and the Three Representational Modalities

The cognitive system contains four basic categories of processes — storage and retrieval, basic information processing, input/output, and knowledge utilization. Of these, the first two categories — storage and retrieval and the information processing function — have pure process structures. That is, their structures are most likely propositionally-based, procedural networks with no nonlinguistic or affective components. Similarly, the decoding and encoding function of the input/output communication processes have pure procedural formats with no nonlinguistic or affective representations. However, with the hybrid processes — input/output and knowledge utilization — the steps or heuristics that address the overall process can involve linguistic, nonlinguistic, and affective components.

The Metacognitive System

The metacognitive system can control any and all aspects of the knowledge domains and the cognitive system. For example, if an individual retrieves and executes a specific mathematical strategy from the mental process domain, the overall execution of this process will be under the control of the metacognitive system. Similarly, if the individual is engaged in the writing process or the decision-making process from the cognitive system, the execution of this process will be under the control of components from the metacognitive domain. To this extent, the metacognitive domain has been described as responsible for the "executive control" of all processes (Flavell, 1979, 1987; Brown, 1978, 1980).

In his theory of intelligence, Sternberg refers to the elements within the metacognitive systems as meta components (Sternberg, 1984a, 1984b, 1986a, 1986b). The components of the metacognitive system have been described as responsible for organizing, monitoring, evaluating, and regulating the functioning of all other types of thought (Brown, 1984; Flavell, 1978a; Meichenbaum and Asarnow, 1979). Within the theory presented here, the components of the metacognitive system are organized into four categories: (1) goal specification, (2) process specification, (3) process monitoring, and (4) disposition monitoring.

Goal Specification

Much of the research on goal-directed behavior encompasses much more than pure metacognitive behavior. It is important to note that in this model, the metacognitive system does not set goals — more specifically, the metacognitive system does not "decide" whether to engage in a presenting task. Deciding whether or not to engage in a presenting task is a function of the self-system. However, once the self-system determines that the individual will engage in a given task (i.e., a presenting task), it is the job of the goal specification function within the metacognitive system to determine the exact nature of the situation when the task has been completed — in technical terms, to determine the "end state" of the task (Hayes, 1981). To illustrate, assume that a student is in a mathematics task and is daydreaming about an upcoming volleyball game. However, she suddenly becomes aware of the teacher exhorting the students to pay particular attention over the next few minutes because he will be covering information that will be on the final examination. It will be the system of beliefs in the self-system that determines whether to change the status quo — daydreaming about the volleyball game, and engage in the new task — attending to the mathematics information. It is the self-system, then, that sets the overall goal of "understanding the mathematics content."

This singular act of deciding whether or not to engage in a presenting task has been referred to as "crossing the Rubicon" (Garcia and Pintrich, 1993; Pintrich and Garcia, 1992) in that once an overall goal is set by the self-system, the other elements of thought — metacognitive system, cognitive system, knowledge domains — are dedicated to accomplishing the task.

The goal specification function within the metacognitive system, then, will take the general goal passed down from the self-system, and determine its specifics. Using the example of the girl in the mathematics class, once the self-system has passed on the general goal, the goal specification function within the metacognitive system establishes specific targeted end states for the task (e.g., "I'm going to listen in such a way that I know the general topics that will be on the test. I won't try to understand them in depth right now. I'll study those topics later.")

Process Specification

The process specification function is charged with identifying or activating the specific skills, tactics, and processes that will be used in accomplishing the goal that has been passed on by the self-system and operationalized by the goal specification function of the metacognitive system. In some cases, this process is relatively straightforward in that the task identified involves process components that are very familiar to the individual. For example, assume an individual has determined that she will engage in the task of mowing the front lawn and has established a specific end state for that task (e.g., a specific level of precision that will be acquired). Assuming that the individual has learned the steps and heuristics involved in mowing the lawn, the process specification function does not have to assemble new combinations of algorithms, tactics, and processes. This function simply executes the retrieval of the known steps and heuristics. However, when the learner is engaged in a novel task, the process specification function must determine not only which algorithms, tactics, and processes to use, but the order in which they will be executed. If the task is highly unfamiliar to the individual, the process specification function might even have to invent a new process specific to the task. In such situations, the success of the individual is dependent on the extent to which the process specification function has designed a new process that is "strategic" in nature — i.e., makes the best use of available resources (Paris, Lipson and Wixson, 1983). Snow and Lohmann (1989) explain that this type of thinking requires a great deal of "conscious thought" as opposed to the more "automatic thought" that is used in routine situations — situations that are quite familiar to the learner.

Process Monitoring

The process monitoring function monitors the effectiveness of the actual algorithms, tactics, and processes that are being used in the task. Psychologist Baddeley has referred to this function as the central executive (Baddeley, 1986, 1990; Baddeley, Grant, Wright and Thomson, 1975; Baddeley and Hitch, 1974; Baddeley and Lewis, 1981; Baddeley, Lewis and Vallar, 1984). As its name implies, the process monitoring function is charged with making executive decisions regarding the use and timing of processes and resources. If an aspect of the "strategic plan" that has been designed by the process specification function breaks down, the process monitoring function will make note of this breakdown and call for the design of a new plan.

Disposition Monitoring

The disposition monitoring function addresses the extent to which the task is carried out in ways that optimize the effectiveness of the algorithms, tactics, and processes being used. Stated differently, this function monitors how one approaches the task that has been selected — how one is "disposed" to the task. If one incorporates the work of Amabile (1983), Brown (1978, 1980), Costa (1984, 1991), Ennis (1985, 1987a, 1987b, 1989), Flavell (1976, 1977), Paul (1984, 1986, 1990) and Perkins (1984, 1985, 1986), a number of dispositions that would be monitored by this aspect of the metacognitive system can be identified. These include monitoring:

- accuracy and precision
- clarity
- restraint of impulsivity
- intensity of task engagement
- task focus

To illustrate, while the individual is engaged in mowing the front lawn, she might monitor the extent to which she maintains a focus on the task at hand (i.e., does not become distracted) and maintains high energy (maintains intensity). It should be noted that the use of the activation of the various dispositions is not generally automatic. Rather, individuals must consciously decide to approach a given task with an eye toward accuracy, clarity, restraint of impulsivity, and so on. Perhaps for this reason, the aspect of metacognition has been associated with high "intelligence" or "intelligent behavior" (Costa, 1991).

Salomon and Globerson (1987) refer to the use of various dispositions as being "mindful." They describe "mindfulness" in the following way:

> . . . the individual can be expected to withhold or inhibit the evocation of a first, salient response, to examine and elaborate situational cues and underlying meanings that are relevant to the task to be accomplished, to generate or define alternative strategies, to gather information necessary for the choices to be made, to examine outcomes, to draw new connections and construct new structures and abstractions made by reflective type processes. (Salomon and Globerson, 1987, p.625)

The Metacognitive System and the Three Representation Modalities

To a great extent, the metacognitive system is comprised of pure procedural structures with no nonlinguistic or affective elements. Additionally, each of the four metacognitive functions — goal specification, process specification, process monitoring, and disposition monitoring — are, to a great extent, innate. There is, however, some informational knowledge within the metacognitive system that is typically learned by an individual. For example, an individual might learn ways of being more strategic when utilizing the process specification function. Similarly, an individual might learn about the nature and importance of various dispositions. This learned knowledge would most likely be represented in linguistic, nonlinguistic, and even affective modalities.

The Self-system

The self-system consists of an interrelated system of beliefs and processes. It is the interaction of these beliefs and processes that produces the goals that are executed by the metacognitive system. Specifically, the self-system determines whether an individual will engage in or disengage in a given task; it determines what is attended to from moment to moment. As mentioned previously, once the self-system has determined that a presenting task will be accepted, the functioning of all other elements of thought (i.e., the metacognitive system, the cognitive system, and the knowledge domains) are, to a certain extent, dedicated or determined. This is why the act of the self-system selecting a task has been referred to as "crossing the Rubicon."

There are five basic categories of beliefs within the self-system. Beliefs about: (1) self-attributes, (2) self and others, (3) the nature of the world, (4) efficacy, and (5) purpose. It is this system of beliefs that constitute what some researchers refer to as one's epistemology, ontology, and world view (Bartunek, 1988; Bagwell-Reese and Brack, 1997; Mau and Pope-Davis, 1993). As Kluckhohn and Strodtbeck (1961) note, it is this system that addresses fundamental perceptions such as the relationship of human beings to nature, the temporal focus of human nature, and the basic purpose of life.

Self-attributes

Researchers and theorists such as Bandura (1977), Harter (1980, 1982), Connell and Ryan (1984), and Markus (Markus and Rovulo,1990; Markus and Wurf, 1987) have demonstrated that one of the most important aspects of one's sense of self is his beliefs about personal attributes. These beliefs are commonly thought of as existing in categories such as beliefs about physical appearance, intellectual ability, athletic ability, social ability, and so on. It is the combined effect of these beliefs that constitutes one's overall self-concept of self. To illustrate, an individual might have a belief that his physical appearance is inferior to those of his peers, but his intellectual ability is higher, his athletic ability is about average, and so on.

Self and Others

Beliefs about self and others deal with one's perception of the nature of formal and informal groups and their relationship to the individual. For example, an individual will have a set of beliefs about the nature of her family and her status within that unit, the defining characteristics of the group she thinks of as her peers and her status within that group. The extent to which an individual perceives that she has high status within groups that she values determines the individual's overall sense of acceptance.

Some psychologists (e.g., Combs, 1962, 1982; Rogers, 1961) assert that human beings have an innate drive for acceptance within one or more groups — individuals have a need to perceive that they "belong." If this is accurate, then one's perceptions regarding his or her status in valued groups will have a profound effect on motivation.

Nature of the World

Beliefs about the nature of the world deal with the nature of the world in both physical and sociological terms. Within this category would be an individual's causal theories about the relationship of various entities. For example, within this category an individual will have "theories" about why specific events occur. These will include their beliefs about physical, emotional, sociological, and supernatural forces and how they came to affect specific situations and events.

Some psychologists explain that it is this category that determines one's disposition regarding the general nature of the world. For example, Bagwell-Reese and Brack (1997) explain that individuals can believe the world at large represents a hostile environment, a neutral environment, or a friendly environment. In general, a belief in a friendly world "generates more flexibility in behavior" than does a belief in a hostile world.

Efficacy

Bandura's (1977, 1982, 1991, 1993, 1996, 1977) theories and research have brought the role of beliefs about efficacy to the attention of psychologists and educators. In very simple terms, beliefs about efficacy address the extent to which an individual believes she has the resources or power to change a situation. Bandura explains that some psychologists assume that human beings have an innate need to control their immediate environment and their lives in general. This striving for control of one's life has been described as an inborn drive (Deci and Ryan, 1985; White, 1959), an "intrinsic necessity of life" (Adler, 1956), "a primary motivational propensity" (DeCharms, 1978), "a motive system" that impels the organisms (Harter, 1991), and a universal "inborn desire" for competence (Skinner, 1995). However, Bandura's research indicates that a sense of efficacy is not necessarily a generalizable construct. Rather, an individual might have a strong sense of efficacy in one situation, yet feel relatively powerless in another. Seligman's research (1990, 1994) also attests to the situational nature of one's sense of efficacy and underscores the importance of these beliefs. He has found that a low sense of efficacy can result in a pattern of behavior that he refers to as "learned helplessness."

Purpose

This category of self-system beliefs deals with one's perception about purpose in life. Philosophers such as Frankl (1967) and Buber (1958) have demonstrated that beliefs about one's ultimate purpose are a central feature of one's psychological makeup. It is important to note that the existence of this category does not imply that all individuals innately believe that life is "purposeful." Indeed, an individual may come to the conclusion that life has no purpose. However, the individual would still have beliefs regarding the dimension of purpose. These beliefs would simply be that there is no overarching purpose to life.

A strong case can be made that this set of beliefs ultimately exerts control over all other elements in the self-system because the purpose or purposes identified for one's life dictates what the individual considers important. To illustrate, assume that an individual's beliefs that her purpose in life (or one of her purposes) is to use her talents to contribute to the benefit of others. As a consequence, she will consider those things important that contribute to this goal. She will then encode specific persons, situations, events, situations, and the like as important or not based on whether they are perceived as instrumental for realizing this purpose. Elements that are not perceived as instrumental to the realization of this purpose would be encoded as unimportant. Elements that are perceived as instrumental would be encoded as important. For example, if the individual believes that acceptance within a particular group will most

6.1

probably enhance her skills and abilities, then she will consider her status within that group important and will be likely to engage in tasks that will help her gain access to that group.

An individual's articulated or unarticulated purposes in life, then, establish a perceived importance for every self-attribute an individual possesses, and every person, place, thing, and event within that individual's constellation of beliefs.

The Process of Motivation and Attention

It is the interaction of the beliefs within the self-system and a control mechanism that dictates motivation and attention. To illustrate, those who ascribe to a cybernetic perspective of human behavior (e.g., Powers, 1973; Glasser, 1981) assert that an individual will have a "desired status" for everything perceived as valuable. As described previously, value is a function of beliefs about life purpose. For example, if an individual has encoded his physical appearance as important based on some belief about life purpose, he will naturally attach a relatively high desired status to his beliefs about physical appearance. He will desire to be physically attractive.

Cybernetic theory also postulates the existence of a "control mechanism." It is the task of the control mechanism to determine the extent to which the perceived status matches the desired status relative to a particular situation. If there is a discrepancy between the desired status in a given situation and the perceived status, then the individual has reason to act, reason to change the status quo.

Given this set of relationships between the categories of beliefs and the control mechanism, one can operationally describe motivation. Specifically, high motivation will exist under the following conditions:

- The individual has a desired status relative to some personal attribute, position within a group, and so on that is unrealized. The perceived status does not match the desired status.
- The individual believes that he has some power to change his current status relative to the personal attribute, position within a group, etc. The individual has a positive sense of efficacy.

Low motivation occurs under the following conditions:

- There is no discrepancy between the desired status and the perceived status. This occurs when the desired status for an attribute, peer group, etc., has been met. This will be true of something that has a high desired status that has been met or a low desired status that has been met.

Finally, negative motivation (i.e., avoidance) will occur under the following conditions:

- There is a discrepancy between the desired status and the perceived status, but the individual has low efficacy beliefs relative to that personal attribute, position within a group, and so on.

Given an understanding of the mechanics of motivation, attention is a fairly straightforward matter. Specifically, attention is the natural consequence of high motivation. One attends to those things that come across his perceptual field for which he has high motivation (Pinker, 1997).

It is useful to distinguish here between motivation that emanates from the self-system versus that which emanates from the limbic system. Damasio (1994) explains that what are referred to as unexplained drives are actually impulses from the limbic system. Sylwester (1995) concurs noting that humans are genetically predisposed to respond to certain stimuli that historically have had a high potential for danger: loud noises, sudden looming shadows. Sylwester notes:

> We're probably not genetically programmed to fear snakes but rather attend to oscillating (snake-like movements). (p. 72)

The discussion here regarding motivation is limited to those urges to change the status quo that emanate from the self-system as opposed to the limbic system. In fact, the theory presented here suggests that the latter should be referred to as something other than motivation (e.g., drive or impulse).

From the discussion above it is evident that beliefs about purpose and efficacy are key to the processes of motivation and, subsequently, attention. The interaction of the components of the self-system might be represented as below.

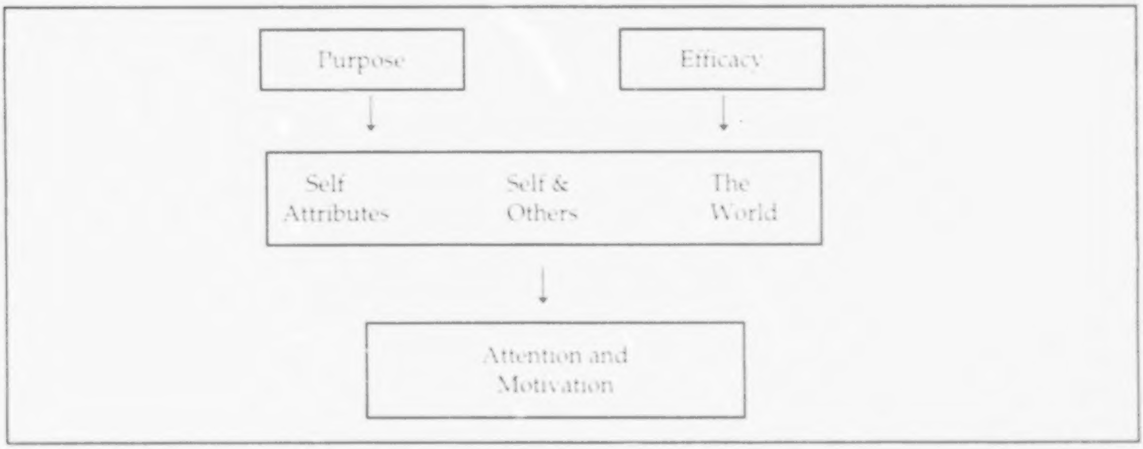

Figure 3.9. Components of the Self-system.

From this diagram one can conclude that changing one's beliefs relative to purpose, efficacy, self-attributes, and so on can drastically alter what an individual attends to and the level of motivation an individual will exhibit to a specific presenting task. The conscious altering of beliefs within any of the five categories of the self-system has been referred to as reframing (see Bergin, 1991; Brack, Brack and Hartson, 1991; Coyne, 1985; Greenberg and Safran, 1981; Jessee, Jurkovic, Wilkie and Chiglinsky, 1982; Kratt, Claiborn and Dowd, 1985; LaClave and Brack, 1989; Swoboda, Dowd and Wise, 1990). To illustrate, if an individual adds a purpose for life that he previously did not have, this added component will increase the potential elements considered important and, consequently, the number of elements for which the individual will exhibit high motivation. From the diagram above, one might accurately conclude that beliefs in the categories of purpose and efficacy most probably generate the greatest changes in attention and motivation since they affect beliefs in the other categories.

The Self-system and the Three Representational Modalities

The self-system is probably the most robust relative to the extent to which its elements are encoded in the three representational modes. In general, all five categories of beliefs within the self-domain are encoded in all three forms. To illustrate, an individual will certainly encode her beliefs about her physical experience as linguistic propositions accompanied by nonlinguistic images, kinesthetic sensations, and so on. Additionally, the individual will probably have strong emotions about her physical appearance particularly if she has a desired status that she perceives as being unmet.

It is also important to note that the self-system is probably responsible for the affective representation within the knowledge domains, the cognitive system, and the meta-cognitive system. That is, these other elements of thought will have affective representations if they are associated with beliefs within the self-system. To illustrate, consider the concept of *automobiles* within the informational domain of knowledge. This information will surely have a linguistic representation (i.e., propositional) and most probably nonlinguistic representations (i.e., images, smells, taste, sounds, and kinesthetic sensations). However, the information will probably not have an affective representation unless some associated beliefs warrant it. For example, the individual might have the belief that possession of a prestigious automobile is important based on a belief that deals with overall life purpose. If the individual does not possess a prestigious automobile, she will have negative affect associated with the general concept automobile and all its associated information. The self-system, then, is the architect of affect for all other elements of thought.

Relationship to Bloom's Taxonomy

In 1956, Benjamin Bloom and his colleagues published two works that revolutionized the way educators thought about content: *The Taxonomy of Objectives in the Cognitive Domain* and *The Taxonomy of Objectives in the Affective Domain*. Bloom and his colleagues had plans to complete a taxonomy of the psychomotor domain, but the work was never completed. At the time, both efforts were considered "cutting-edge" relative to their application of the research and theory on cognition to educational practice. Obviously, educators and psychologists have learned a great deal in the forty-plus years since the publications of the taxonomies. These "new learnings" have disclosed some problems with the Blooms's initial works. Even the brief discussion of this model articulated in Chapters 2 and 3 discloses some omissions in the taxonomies. For example, Bloom's work did not address the metacognitive and self domains, nor did it address the basic distinction between informational knowledge and mental process knowledge. Not surprisingly, the validity of Bloom's taxonomies has been attacked.

Anderson and Sosniak (1994) provide a forty-year perspective on the taxonomy of the cognitive domain noting that it was a watershed work breaking the historical belief that all learning is unidimensional. Bloom's six levels of processing within the cognitive domain provided a strong statement that different types of learning require different types of thought. However, subsequent empirical investigations generated a number of criticisms of the taxonomy (Kreitzer and Madaus, 1994). One of the most common criticisms of the taxonomy was that it oversimplified the nature of thought and its relationship to learning (Furst, 1994). Even though the taxonomy within the cognitive domain expanded the conception of learning, it still assumed a very simple linear relationship among the six levels.

Another weakness in the taxonomy disclosed by empirical studies was that the higher levels of the taxonomy do not seem to be superordinate to the lower levels. Evidence for this was that educators are not able to recognize questions that are specifically designed to represent specific levels of the hierarchy. For example, in studies by Stanley and Bolton (1957), Poole (1972), and Fairbrother (1975), teachers were consistently unable to recognize the taxonomy level a given question was designed to address.

How, then, does the theory presented here improve upon Bloom's efforts? It does so in at least two ways. First, it presents a theory of learning as opposed to a framework. As described in Chapter 1, a framework is a loosely organized set of principles that describes a given phenomenon. Bloom's six levels within the taxonomy represent general categories of information processing. They are certainly useful categories in helping educators understand the multifaceted nature of learning. Indeed, in his 1977 edition of *Conditions of Learning*, Robert Gagne commented on the "ingenious" contributions of the authors of the taxonomy to an understanding of the various categories of learning. However, the taxonomy was not designed to predict specific behaviors (Rohwer and Sloan, 1994), which is one of the defining characteristics of a theory. The theory presented here predicts specific behavior for specific situations. For example, given an understanding of an individual's beliefs within the self-system, one can predict the attention that will be paid to a given task and the motivation that will be displayed.

The second way the theory presented here improves on the taxonomy is that it presents a clear delineation of the flow of data within any learning situation (indeed, within any situation where there is an internal or external stimulus to change the status quo). Processing always starts with the self-system, proceeds to the metacognitive system, then to the cognitive system, and finally to the knowledge domains. The status of the various factors within one element of the theory always affects the status of the various factors within another element. For example, if the self-system contains no beliefs that would render a given task important, then the individual will not engage in the task or will engage with low motivation. If the task is deemed important but a clear goal is not established by the processor within the metacognitive system, execution of the task will break down. If clear goals have been established and effectively monitored but the information processing functions within the cognitive system do not operate effectively, the task will not be carried out. Finally, if necessary information and skill is not present within the knowledge domains, the task will fail.

A clear line of processing did not emerge within Bloom's taxonomy. In fact, the authors of the taxonomy admitted significant problems relative to the flow of processing. For example, the authors explained that "[I]t is probably more defensible educationally to consider analysis as an aid to fuller comprehension (a lower class level) or as a prelude to an evaluation of the material" (p. 144). The authors of the taxonomy further acknowledged the fact that the levels of the taxonomy did not constitute a hierarchy.

> Although Evaluation is placed last in the cognitive domain because it is regarded as requiring to some extent all the other categories of behavior, it is not necessarily the last step in thinking or problem solving. It is quite possible that the evaluation process will in some cases be the prelude to the acquisition of new knowledge, a new attempt at comprehension or application, or a new analysis and synthesis. (p. 185)

In all, then, although it carries the title taxonomy, Bloom's framework only approaches a taxonomy. As Rohwer and Sloane note, "The structure claimed for the hierarchy, then, *resembles* a hierarchy" (p. 47).

Summary

In this chapter, the knowledge domains and the cognitive, metacognitive, and self-system have been described. The knowledge domains include information, mental processes, and psychomotor skills. The cognitive system includes processes that address storage and retrieval, basic information-processing, communication and knowledge utilization. The metacognitive system includes processes that address goal specification, process specification, process monitoring, and disposition monitoring. The self-system includes five categories of beliefs — self-attributes, self and others, nature of the world, efficacy, and purpose — along with a mechanism that calculates the discrepancy between desired status and perceived status.

These four elements of the mind constitute a hierarchic system in that the self-system exerts control over the metacognitive system, which exerts control over the cognitive system that operates in the knowledge domains.

CHAPTER 4

DESIGN OF META-ANALYSIS

A number of researchers have identified the various considerations that should be addressed in an effective meta-analysis (see Glass, McGaw, and Smith, 1981; Rosenthal, 1991a, 1991b; Wolf, 1986). These include : (1) defining the domain of research, (2) identifying the moderator variables, (3) establishing criteria for inclusion in the study, and (4) determining the type of effect size to be used. Each of these issues is addressed in this chapter.

Defining the Domain of Research

As discussed briefly in Chapter 1, meta-analyses are susceptible to the apples and oranges problem. This occurs when a researcher uses categories of independent variables that are too broad. Stated differently, this happens when a researcher does not adequately specify the domain of research. To guard against the apples and oranges problem, one must adequately specify the domain of research. This involves identifying the primary independent variables as well as modifying or moderating variables.

In this study, the overall domain of interest is the effect of classroom instructional techniques. Additionally, an instructional technique is defined as an alterable behavior on the part of teachers or students. By definition, then, this study did not consider variables such as the following because they are not alterable: use of specific instructional materials, computer-aided instructional programs, demographic variables (e.g., teacher gender, student socio-economic status), school funding, class size, desegregation, and so on. Some of these variables have previously been addressed in other meta-analyses (see Smith, Glass and Miller, 1980; Lipsey and Wilson, 1993).

As discussed in Chapter 1, a number of meta-analyses have previously been conducted on the instructional research that addresses alterable variables. However, at best these efforts have used frameworks as opposed to theories as the organizers for the domain of research. To improve on the previous efforts, this study utilized a theory that postulates the interaction of four elements — knowledge, the cognitive system, the metacognitive system, and the self-system. The four elements create a highly specific categorization system for the research on instruction. To illustrate, if one assumes that a goal of education is to improve student achievement in the knowledge domains, then instructional techniques can be classified by the system they employ to improve achievement within the knowledge domains. For example, an instructional technique that attempts to enhance students' recall of information would be classified as employing a specific function within the cognitive system (i.e., storage and retrieval) to enhance a specific aspect of knowledge (i.e., the informational domain).

Chapter 6 describes the findings when improvement of student achievement in the knowledge domains was considered the primary outcome of instructional techniques. However, some instructional techniques have as their focus improvement in student use of the cognitive system, metacognitive system, or the self-system. That is, some instructional techniques were designed not to enhance student knowledge per se, but to enhance their ability to use one of more of the information processing functions within the cognitive system, or to use the process monitoring function within the metacognitive system or to enhance students' abilities to control and monitor beliefs within the self-system. The assumption underlying all of these techniques is that directly improving the effectiveness of these systems will indirectly enhance students' abilities to learn knowledge since these systems are the tools an individual must use to learn knowledge of any type. Consequently, a second perspective in the instructional research surveyed in the study was to analyze those techniques that were designed to enhance student competence in the three systems. The results of this aspect of the current study are reported in Chapters 7 and 8.

Moderator Variables

In addition to specifying the domain of research, an effective meta-analysis specifies moderator variables. Moderator variables are those that may account for significant variability in effect size associated with the independent variables — they moderate the relationship between the independent and dependent variables (Rosenthal, 1984). Stated differently, moderator variables are independent variables that are not of primary interest to a study but are hypothesized to have causal or correlational relationships with the dependent variables. Consequently, the relationship between selected moderator variables and the dependent variables must be estimated to obtain an accurate picture of the relationship between the independent variables of primary interest and the dependent variables. In this study, eight moderator variables were identified *a priori*: (1) intended user of technique, (2) specificity of instructional techniques, (3) grade level of subject, (4) student ability, (5) duration of treatment, (6) specificity (reactivity) of dependent measure, (7) methodological quality, and (8) type of publication.

Intended User of Technique

Basically, there are two possible users for an instructional technique: teachers and students. A strategy intended to be used by teachers is one that specifies how the teacher should behave to help students learn specific content or to improve a specific skill. For example, providing students with advanced organizer questions is a technique popularized by Ausubel (1968). It is intended to be used *by teachers* to help students learn informational knowledge. A strategy intended for students is one that identifies behaviors students can engage in to better learn specific content or a specific skill. For example, outlining is a technique that is designed to be used *by students* to help them learn informational knowledge.

Specificity of Instructional Technique

Another moderator variable of experimental interest was the extent to which an instructional strategy was described in terms of specific steps or elements. The following scheme was used to code instructional techniques relative to this variable:

Level 1: Explicit technique described.
In this situation an explicit description of the instructional technique was provided for which an effect size was either reported or computed.

Level 2: Explicit technique named.
In this situation an explicit technique was not described in detail; however, the name of the techniques provided enough information to infer a specific technique. For example, if the term "decoding strategy" is used to describe the instructional technique, it implies a set of instructional strategies commonly accepted within the literature on reading instruction.

Level 3: General category.
In this situation, no explicit instructional strategy or strategies could be inferred given the highly general nature of the category within which an effect size was calculated or reported. For example, if an effect size was calculated or reported for the general category termed "teacher questioning" without a description of the types of questions that were used, a level 3 code was assigned.

Grade Level of Students

A third moderator variable examined was the grade level of the students on whom an instructional technique had been tried. A reasonable hypothesis is that instructional technique will have different effects across different grade levels of students. That is, an instructional technique that produces positive effects for students at the high school level might not produce the same effects with students at the elementary school level. Grade levels were categorized into the following intervals:

1) College
2) High School: grades 9-12
3) Middle/Junior High: grades 6-8
4) Upper Elementary: grades 3-5
5) Primary: grades K-2

Student Ability

Another moderator variable of interest in this study was the ability level of the students. One might assume that strategies have differential effects across ability levels. A strategy that works well for low-ability students might not work well for high-ability students. The following categories of student ability were used in this study:

High Ability:	Rated high or above average by experimenter on measure of IQ, aptitude, or achievement
Medium Ability:	Rated medium or average by experimenter on measure of IQ, aptitude, or achievement
Low Ability:	Rated low or below average by experimenter on measure of IQ, aptitude, or achievement

Duration of Treatment

Duration of treatment was defined as the time in weeks that was required to deliver the instructional technique. The following categories of time were used for this variable:

1) One week or less:	1 to 7 days
2) Two weeks:	8 to 14 days
3) Three weeks:	15 to 21 days
4) Four or more weeks:	22 or more days

No *a priori* hypothesis was generated as to the effects of interventions that lasted different lengths of time. However, it was assumed that the duration of an intervention was a significant factor in the practical significance of an intervention. Specifically, an intervention that takes two weeks would be considered less efficient than one that takes one class period but produces the same effect size. In past reviews of the research on instruction, this variable has been found to be a significant consideration. For example, Wang, Haertel, and Walberg (1993, p. 270) found that 75 percent of the 270 studies they reviewed examined instruction on a single occasion, whereas 25 percent examined instruction over time. Hattie, Biggs, and Purdie (1996) found that 37 percent of the studies included in their analysis were implemented over 1-2 days, 13 percent for 3-4 days, 19 percent for 5-31 days, and 31 percent for more than one month.

Specificity (Reactivity) of Dependent Measure

Specificity of the dependent measure refers to the extent to which the dependent measure used in a study was specific to the domain or system to which the instructional strategy was intended. Smith, Glass, and Miller (1980) refer to this moderator variable as the "reactivity of the outcome measure." They note that highly *reactive* instruments are those that reveal or clearly parallel the obvious goals or valued outcomes of the interventions; whereas relatively non-reactive measures are not sensitive to the goals of the intervention (pp. 66-67).

The *a priori* hypothesis for this moderator variable was that those studies utilizing dependent measures that were specific (i.e., highly reactive) to the domain and system for which a strategy was intended would produce larger effect sizes. The following coding scheme was used for this moderator variable:

Level 1:	Dependent measure was designed specifically for the intervention.
Level 2:	Dependent measure was not designed specifically but fit well with the construct being assessed.
Level 3:	Dependent measure was a very general measure or inappropriate for the domain or system under investigation.

Methodological Quality

Some studies used in this meta-analysis provided an evaluation of the methodological quality of the study or studies they included. The vast majority of those studies coded three categories of quality — high quality, medium quality, and low quality. The codings for these studies were simply incorporated into this effort. For studies where methodological quality was not a control factor, the system employed by Smith, Glass, and Miller (1980) was used to code methodological quality. To be judged high on methodological quality, a study must have used random assignments of subjects to groups and had a mortality rate of less than 15 percent and equivalent between groups. If mortality was higher or nonequivalent between experimental and control groups, methodological quality was still rated high if the scores of the terminators in the posttest statistics were reported, or if the equivalence of terminators and nonterminators was established. Methodological quality was rated as medium under the following conditions: (1) the study used randomization but mortality was high or differential, (2) the study began using randomization but then resorted to using other allocation methods, (3) the study utilized a well-designed matching process. Low quality studies were those where intact groups were utilized (i.e., no attempt or weak attempts were made at matching) or where mortality was severely disproportionate.

Type of Publication

This moderator variable dealt with the type of publication in which a study was reported. It is generally assumed that publications in highly competitive, refereed venues will report larger effect sizes than publications in less rigorous and less competitive venues. The logic underlying this assumption is that studies reported in more competitive and rigorous venues will control better for extraneous variables and, therefore, produce less inflated effect sizes. Durlak (1995) explains that this artifact is commonly referred to as publication bias that is related to the "file drawer problem."

> Publication bias is related to the so called "file drawer problem" (Rosenthal, 1979) which is the tendency for authors not to submit and journal editors not to accept for publication studies that fail to achieve statistically significant results. As a result, experiments that do not turn out as expected languish in investigator's file drawers, whereas the published literature contains a preponderance of positive fundings. (Durlak, 1995, pp. 322-323)

Two categories were used to code this moderator variable: published studies and unpublished studies. Published studies were defined as those that appear in journals and books. Unpublished studies were defined as those appearing in dissertations, convention papers, or technical reports.

Inclusion of Studies

The selection of studies to be included in a meta-analysis is commonly cited as one of the most critical design variables. As Durlak (1995) notes: "The ultimate goal of a literature research is to obtain a representative and nonbiased sample of relevant investigations. . ." (p. 323). Commonly, three major techniques are employed to locate relevant studies: computer searches, manual searches, and examinations of reference lists in identified studies. Computer searches usually employ one or more of the following data bases: PsychLIT, MEDLAS, Dissertation Abstracts, and ERIC. After computer searches have been completed, researchers will commonly hand-search specific journals that are particularly related to the topic. For example, if a meta-analysis concerns a topic in reading, the researcher may hand-search back issues of *Reading Research Quarterly* over a ten year period of time. Finally, when studies are found that cite other studies whose titles appear to be particularly relevant, these secondary sources are also retrieved.

Because of the breadth of this meta-analysis, a somewhat different search protocol was employed from that described above.

> Step 1: Identification of studies from the Fraser et al. data base.
>
> At its most general level, this study was an analysis of meta-analyses. To date, a number of such analyses have been conducted by Hattie, Walberg, Wang and their colleagues (see Hattie, 1992; Hattie, Biggs and Purdie, 1996; Wang, Haertel and Walberg, 1990; 1993). Virtually all of these studies used as their bases 135 meta-analyses that were reported in Fraser et al. (1987). This data base of meta-analyses was considered the

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foundation for the present effort. However, all 135 meta-analyses from the Fraser et al. study were not appropriate to the present effort since the Fraser study addressed variables that are beyond the scope of this effort. Specifically, where this study was focused on the classroom only, the Fraser study addressed educational practices both inside and outside the classroom. For example, meta-analytic studies of variables outside of the classroom like desegregation policies, management policies and school goals were included in the Fraser et al. study. Additionally, the current study focused on those variables within the classroom that were considered alterable via explicit changes in teacher or student behavior, whereas the Fraser study included variables that are not alterable by the teacher or student such as teacher gender and experience, student gender, socio-economic status, and aptitude. Consequently, only those meta-analyses from the Fraser et al. data base that addressed alterable variables within the classroom were utilized.

Step 2. Identification of meta-analyses that have been conducted since the Fraser et al. study.

The Fraser et al. study was published in 1987. Thus, any meta-analysis conducted from 1987 on (assuming that Fraser and his colleagues completed their work in 1986) would not be reflected in their work. Consequently, an ERIC search was conducted using the keyword "meta-analysis" covering all entries from 1966 to the present. The titles of these studies were reviewed and those deemed relevant were retrieved and included in this effort.

Step 3. Hand-search of selected journals.

Since this meta-analysis addressed general instructional techniques, two sources were considered the most likely to contain pertinent meta-analytic studies: The *Review of Educational Research* (RER), and *Review of Research in Education* (RRE), both publications of the American Educational Research Association. RER is published quarterly and RRE is published yearly. All entries over the last 25 years were examined for both publications.

Selection and Computation of Effect Sizes

One of the main advantages of using effect size as the scale with which to analyze the results of studies on instruction is that all studies can be interpreted using the same metric. As discussed in Chapter 1, an effect size is directly interpretable in terms of percentile gain for the "average" subject in the control group (i.e., the percentile score in the control group distribution of the mean score on the experimental group distribution).

For a number of reports utilized in this meta-analysis, effect sizes were already calculated and reported. In such cases, no calculation of effect size was necessary. However, in some cases, it was necessary to compute effect sizes since they were not reported in the original studies. Given that researchers have different ways to compute effect sizes, it was necessary to select among the various techniques. Common ways to calculate effect sizes are: Glass's delta, Cohen's d, and Hedges g. (For a comprehensive discussion of the differences among various ways of estimating effect sizes, see Hedges and Olkin, 1985.) The differences between these three types of effect sizes are depicted in Figure 4.1.

$$\text{Glass's delta} = \frac{M_1 - M_2}{\text{sd control group}}$$

$$\text{Cohen's d} = \frac{M_1 - M_2}{\text{Sigma}}$$

$$\text{Hedges' g} = \frac{M_1 - M_2}{\text{sd}}$$

Where:

M_1 = Mean of experimental group
M_2 = Mean of control group
sd = Sample standard deviation
Sigma = Population standard deviation

Figure 4.1. Types of Effect Size Estimates.

As Figure 4.1 illustrates, the difference in effect size estimators is the denominator used to scale the difference between the mean of the experimental and control groups. Glass's delta utilizes the standard deviation of the control group, Cohen's *d* utilizes the standard deviation of the population, and Hedges' *g* utilizes the pooled standard deviation from the experimental and control groups.

When the population standard deviation was available, Cohen's *d* was utilized. Such would be the case when a standardized dependent measure was used and the population variance or standard deviation could be obtained from that measure. If the population standard deviation was not available but the standard deviation from experimental and control groups were, Cohen's *d* was used. Finally, when only the control groups' standard deviation was available, Glass's delta was used. Rosenthal (1991a) discussed the advantages and disadvantages to the various effect size estimates.

In a number of cases, means and standard deviation were not available. In these situations, effect sizes were estimated using conversion formulas that have been reported in the literature (see Rosenthal, 1991a; Wolf, 1986). Table 4.1 illustrates some of the formulas that were used.

Table 4.1
Conversion Formulae

Statistic to be Converted	Formula for Transformation	Comment
t	$d = \frac{2t}{\sqrt{df}}$	
F	$d = \frac{2\sqrt{F}}{\sqrt{df}}$ (error)	Used only for comparing 2 means
r	$d = \frac{2r}{\sqrt{1-r}}$	
X^2	Convert X^2 to r using the formula $r = \frac{\sqrt{X}}{n}$ Then convert r to d	Used only for 2x2 contingency table

Combining Multiple Effect Sizes

One of the major decisions that must be made in a meta-analysis is the determination of how multiple effect sizes from the same study will be aggregated. Glass (1981) takes a very robust view of combining non-independent effect sizes allowing for their averaging. Others take a less robust view. For example, in their meta-analysis of research on reading comprehension, Haller, Child, and Walberg (1988) reported the following protocol for aggregating non-independent effect sizes:

> The number of effect sizes in each study ranged from 1 to 20. To avoid having a few studies with a large number of effect sizes bias the statistical results, each study was assigned a weight of 1. For example, if a study had only one effect size, that effect size would have a weight of 1, but if a study had 20 effect sizes, each individual effect size would have a weight of 1/20. This not only gives each study equal weight but also complies

> with the statistical requirement for inference by allowing one degree of freedom for each piece of independent information. (p. 7)

In this study, the less robust approach described by Heller, Child and Walberg (1988) was employed.

Notation and Symbols

One of the problems with the current status of meta-analytic procedures is that no uniform notation or symbol system has been developed. The system used here is drawn from previous works. However, the principle guiding the selection and creation of the notational and symbol system used in this study was to limit as much as possible the need for a technical background to read this report.

Unless otherwise indicated, the following symbols and notations are specified as follows:

ES = average effect size across a set of effect sizes
es = effect size for a single study
N = number of subjects
n = number of effect sizes
M = mean
SD = average standard deviation across a set of studies
sd = standard deviation for a single study
P = percentile

Summary

This chapter described the overall research design used in this study. The knowledge domains and the cognitive, metacognitive, and self-system were the main categories into which instructional techniques were organized. This categorization system allowed for an analysis of the research on instruction from a number of perspectives. This chapter also described eight moderator variables that were analyzed in an effort to appropriately qualify the findings. Finally, this chapter described the protocol used to select studies for inclusion in the meta-analysis, along with the methods that were employed to compute effect sizes.

CHAPTER 5

GENERAL FINDINGS AND THE MODERATOR VARIABLES

In all, this meta-analysis utilized over 4,000 effect sizes that involved an estimated 1,237,000 subjects. The overall effect sizes computed for the knowledge domains and the cognitive, metacognitive, and self-systems are reported in Table 5.1.

Table 5.1
Average Effect Sizes for Knowledge and the Three Systems

	ES	n	SD	Gain
Knowledge	.60	2475	.91	P[illegible]-P[illegible]
Cognitive System	.75	991	.82	P[illegible]-P[illegible]
Metacognitive System	.55	51	.78	P[illegible]-P[illegible]
Self-system	.74	540	.91	P[illegible]-P[illegible]
Overall	.65	4057	.87	P[illegible]-P[illegible]

Table 5.1 indicates that the overall effect size across the knowledge domains and the three systems was .65. An effect size of .65 can be understood most clearly by referencing it to percents of populations of persons. To illustrate, assume that a random sample of students is drawn from the population at large. Also assume that the population and the representative sample is normally distributed in their achievement relative to the knowledge domains and the three systems (i.e., their achievement follows the familiar bell-shaped curve). Assume now that the representative sample of students receive the instructional interventions described in the studies identified for this meta-analysis. The average achievement of these sample students averaged across the knowledge domains and the three systems will be higher than the average achievement of the population from which they were drawn by a factor of .65 standard deviations. More specifically, the average achievement of the sample students will be at the 74th percentile of the population from which they were drawn — a gain of 24 percentile points. This is depicted in Figure 5.1.

The individual effects of the instructional techniques surveyed in this study on the knowledge domains and the three systems are depicted in Figures 5.2a, 5.2b, 5.2c, and 5.2d.

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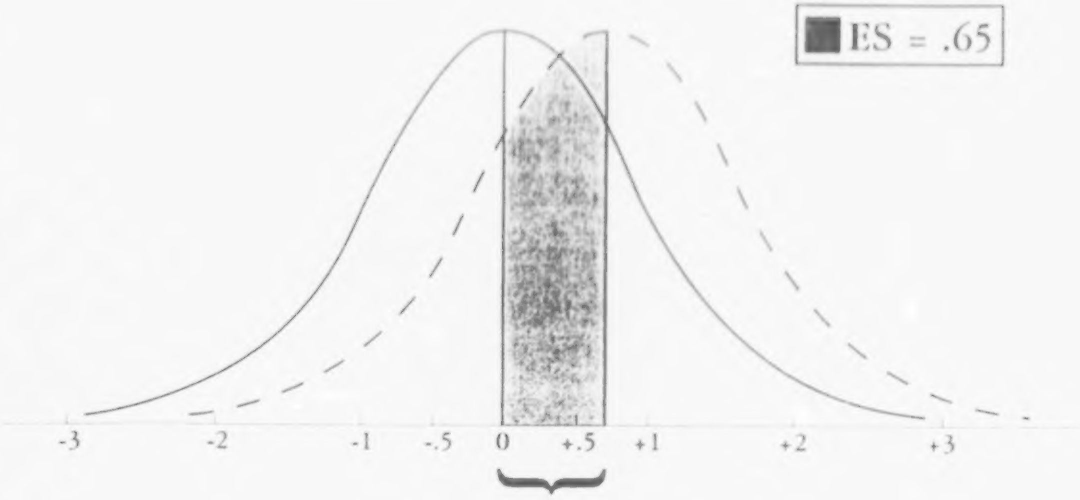
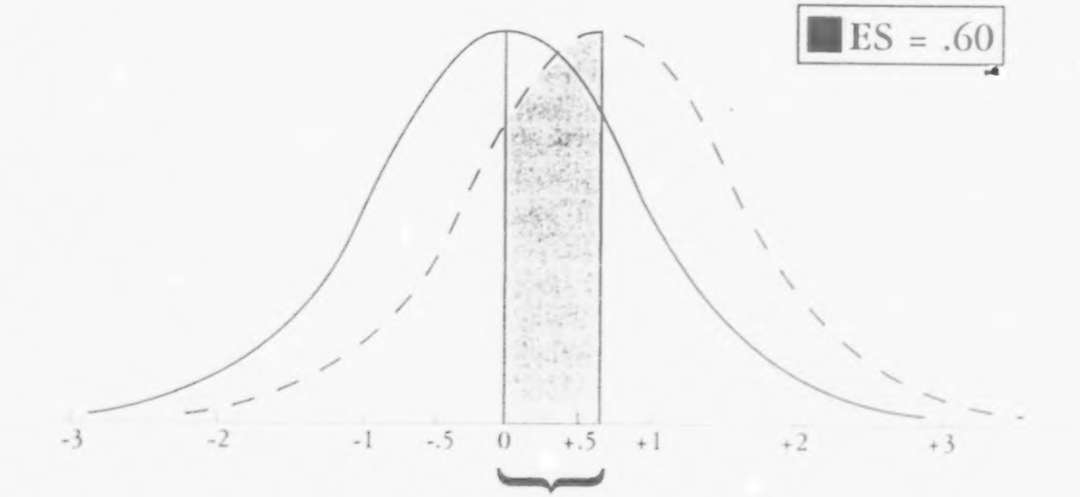


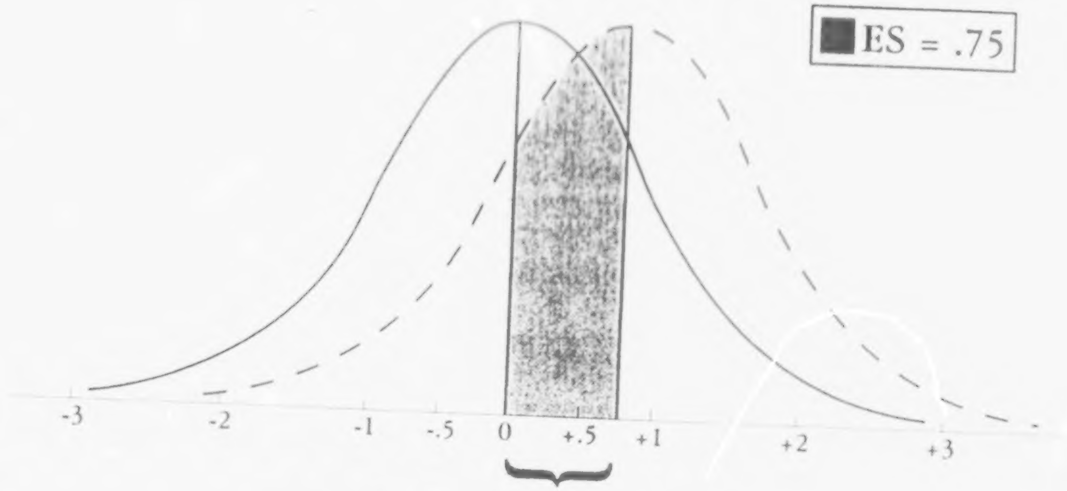
Percentile Point Gain = 24

Figure 5.1. Overall Effect of Instruction on Knowledge and the Three Systems.



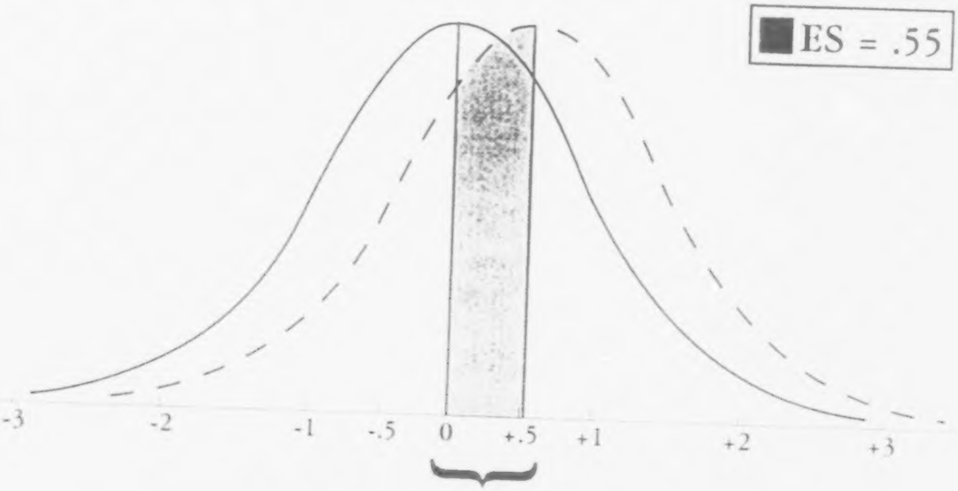
Percentile Point Gain = 23

Figure 5.2a. Overall Effect of Instruction on the Knowledge Domains.



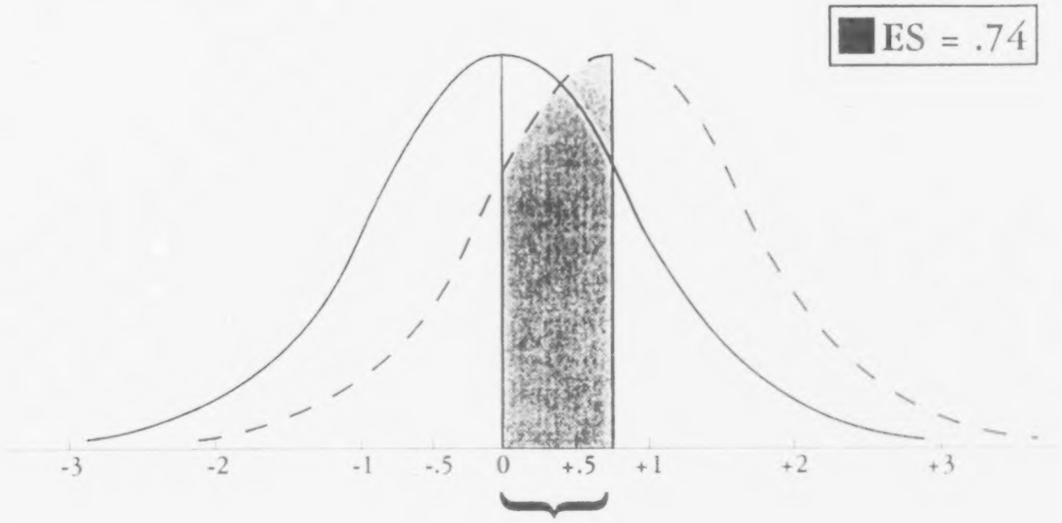
Percentile Point Gain = 27

Figure 5.2b. Overall Effect of Instruction on the Cognitive System.



Percentile Point Gain = 21

Figure 5.2c. Overall Effect of Instruction on the Metacognitive System.



Percentile Point Gain = 27

Figure 5.2d. Overall Effect of Instruction on the Self System.

Figures 5.2 a through 5.2d illustrate that utilization of instructional techniques produce an increase of achievement within the knowledge domains of 23 percentile points, an increase in competence within the cognitive system of 27 percentile points, an increase in competence within the meta-cognitive system of 21 percentile points, and an increase in competence within the self-system of 27 percentile points.

Another way of grasping the significance of these findings is to utilize Rosenthal and Rubin's (1982) binary effect size display or BESD. Rosenthal and Rubin's BESD allows one to interpret an effect size in terms of the proportion of treatment versus control subjects above a common success threshold. In BESD terms, the overall effect size of .65 can be represented as a contrast between a treatment group (i.e., one that utilizes a given instructional technique) with a success rate of 65.5 percent versus a control group with a success rate of 34.5 percent. A 31 percentage point spread between treatment and control success rates is not a small difference. Correspondingly, an effect size of .60 (for the knowledge domains) translates to a 29 percentage point spread between success rates of experimental versus control groups; an effect size of .75 (for the cognitive system) translates into a 35 percentage point spread; an effect size of .55 (for the metacognitive system) translates into a 27 percentage point spread, and an effect size of .74 translates into a 35 percentage point spread.

The impressiveness of these findings are put in perspective when one compares them with effect sizes and BESD's from other disciplines. For example, Rosenthal (1991a) has observed that a medical study on the effects of aspirin on heart attacks was judged conclusive and prematurely ended when the effect size reached .07 which, in BESD format, is equivalent to less than a 3.5 percentage point difference in success rate between treatment and control groups. Lipsey and Wilson (1993) have identified the effect sizes and corresponding BESDs for a number of studies in medicine and psychology. These are reported in Table 5.2.

Table 5.2
Comparative Effect Sizes and BESDs in the Field of Medicine

	ES	BESD
Dipyridamole an angina (Sacks, Ancona-Berk, Berrier, Nagalingam & Chambers, 1988)	.24	.12
Drug treatment on arthritis (Felson, Anderson and Meenan, 1990)	.45 to .77	.22 to .36
Cyclosporine an organ rejection (Rosenthal, 1991b)	.39	.19
Anticoagulants on thrombalsam bolisin rates (Chalmers, Matta, Smith & Kunzler, 1977)	.30	.15
Drug treatment for behavior disorders (Kavale and Nye, 1984)	.28 to .74	.14 to .35
Drug treatment for hyperactivity (Kavale 1982; Ottenbacher and Cooper, 1983; Thurber and Walker, 1983)	.47 to .96	.23 to .43
Hypertension drug therapy (Beto and Bansal, 1992)	.11 to .28	.05 to .14

The range of effect sizes in Table 5.2 is from .11 to .96 (BESD range .05 to .43). One might legitimately conclude that the findings in education compare well to those in medicine and psychology. In fact, the findings in education appear to be so positive that it has led some meta-analysts to comment. For example, in their review of techniques within education and psychology, Lipsey and Wilson (1993) noted:

> There is little in conventional reviews and past discussion of these treatment areas, either individually or collectively, that prepares a reviewer for the rather stunning discovery that meta-analysis shows nearly every treatment examined to have positive effects.
>
> Indeed, the effect size distribution. . .is so overwhelmingly positive that it hardly seems plausible that it presents a valid picture of the efficacy of treatment per se. (p. 1192)

Similarly, in his review of the research on instruction, Hattie (1992) remarked that the effect sizes from 134 meta-analyses were overwhelmingly positive and remarkably generalizable.

Of course, Table 5.1 does not break down the findings of this meta-analyses into specific types of outcomes or specific types of instructional techniques and, therefore, suffers from the same "apples and oranges" problem of other studies. However, the discussions in Chapter 6 through 9 may be specific enough to address this issue. Prior to that more specific discussion, though, it is necessary to consider the effects of the moderator variables introduced in Chapter 4 since these variables might represent factors that artificially inflate or deflate the relationship between a specific outcome and a specific instructional technique.

The Moderator Variables

In this section the eight moderator variables introduced in Chapter 4 are discussed.

Intended User of the Strategies

The intended user of the strategy refers to whether a technique was designed for use by the teacher or student. The results for this variable are reported in Table 5.3.

Table 5.3
Intended User

Intended User	**ES**	**n**	**SD**	**Gain**
Teacher	.61	2893	.82	P_{50}-P_{73}
Student	.73	1164	.71	P_{50}-P_{77}

As evidenced by Table 5.3, the vast majority of techniques identified in this meta-analysis were designed to be used by teachers. However, those designed to be used by students had a higher average effect size (i.e., .73 versus .61). This difference was statistically significant (p<.05, two tailed). Techniques designed to be employed by students produced an average percentile gain of 27 points; techniques designed to be employed by teachers produced an average percentile gain of 23 points. This difference might be due to the fact that techniques employed by students automatically demand the use of the metacognitive system, thus increasing the extent to which students generate strategies, monitor the effectiveness of those strategies, and employ various dispositions like seeking accuracy or restraining impulsivity. The overall effectiveness of strategies that engage student metacognition is discussed in Chapter 6.

Specificity of Instructional Techniques

The specificity of the instructional techniques was coded using a scale with three values: Level 1: technique was described in highly specific terms; Level 2: the name of the instructional technique allowed one to infer the specific steps in the technique; Level 3: the technique belonged to a general category of techniques or no specific steps were presented or could be inferred. The *a priori* hypothesis was that the more specific instructional techniques would produce the higher effect sizes. Results for this moderator variable are reported in Table 5.4.

Table 5.4
Specificity of Instructional Technique

Level of Specificity	ES	n	SD	Gain
Level 1	.67	883	.72	P_{50}-P_{75}
Level 2	.64	1024	.68	P_{50}-P_{73}
Level 3	.64	2150	.79	P_{50}-P_{74}

The results of the analysis did not support the *a priori* hypothesis. Although there is a difference between the average effect size for Level 1 (more specific strategies) versus Levels 2 and 3, this difference was not statistically significant (p<.05, two-tailed).

Grade Level of Students

This moderator variable was coded using a scale with five values: college (Col), high school (HS), middle school/junior high (M/JH), upper elementary (UEL), and primary (Pri). The results of this variable are reported in Table 5.5.

Figure 5.5
Grade Level of Students

	ES	n	SD	Gain
Col	.64	147	.92	P_{50}-P_{74}
HS	.71	241	1.04	P_{50}-P_{76}
M/JH	.68	95	.84	P_{50}-P_{75}
UEL	.67	142	.72	P_{50}-P_{75}
Pri	.64	87	.75	P_{50}-P_{74}

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Table 5.5 reports differential effects across the grade level categories. However, none of these differences was significant (p<.05, two-tailed).

Student Ability

This moderator variable was coded using a scale with three values: high average ability (H), medium ability (M), and low ability (L). The results are reported in Table 5.6.

Table 5.6
Student Ability

	ES	n	SD	Gain
H	.91	942	.71	P[illegible]-P_{82}
M	.70	1044	.65	[illegible]
L	.64	824	.78	[illegible]

The differences in average effect sizes between the high ability students versus the medium and low ability students was statistically significant (p<.05, two-tailed). This finding might be considered consistent with those studies that report a large effect for the impact of aptitude or ability on achievement in general (e.g., Fraser, et al., 1987; Bloom, 1976; Lysakowski and Walberg, 1982). However, those studies examined the effects of prior knowledge as a moderator variable. The variable of prior knowledge might not be comparable with that of student ability. In any event, these results indicate that some instructional techniques have different effect sizes for high ability students than they do for middle and low ability students.

Duration of Treatment

This moderator variable was coded using a scale with four values: one week (1W), two weeks (2W), three weeks (3W), and four or more weeks (4+W). The results are reported in Table 5.7.

Table 5.7
Duration of Treatment

	ES	n	SD	Gain
1W	.67	421	.74	[illegible]
2W	.72	401	.54	[illegible]
3W	.64	24	.82	[illegible]
4+W	.52	20	.31	[illegible]

Those studies coded as lasting four or more weeks had a significantly lower average effect size (p<.05, two-tailed) than all other studies. Studies coded as lasting two weeks had a significantly higher effect size (p<.05) than studies coded as lasting three weeks or four or more weeks. At face value, these findings appear contradictory to the many studies reporting large effect sizes for the amount of time a subject is studying (see Fraser, et al., 1987). Specifically, in previous studies, higher achievement was associated with larger durations of time spent studying a topic. However, the time variable reflected in Table 5.7 addresses the length of the intervention (i.e., new instruction technique) that was employed within a study as opposed to how much time was spent on a specific topic. Additionally, when interpreting Table 5.7, one must note that many more studies were found that employed interventions of one or two week durations than three or four week durations. Thus, the lower effect sizes for intervention with longer durations might simply be a function of sampling error.

Specificity (Reactivity) of Dependent Measure

This moderator variable was coded using a scale with three values: Level 1 — highly specific, designed for treatment; Level 2 — not designed for treatment but appropriate; Level 3 — very general. The results are reported in Table 5.8.

Table 5.8
Reactivity

	ES	n	SD	Gain
Level 1	.97	872	.62	P_{50}-P_{84}
Level 2	.91	505	.74	P_{50}-P_{82}
Level 3	.55	2680	.92	P_{50}-P_{71}

The average effect sizes reported in Table 5.8 indicate that the level of reactivity of the dependent measure had a strong influence on the effect size within a given study. The more reactive or sensitive a dependent measure was to the intended outcomes of the study, the larger the effect size. Studies in which the dependent measure was given a Level 1 rating had an effect size of .97, indicating a percentile gain of 34 points; studies in which the dependent measure was given a Level 3 rating had an effect size of .55, indicating a percentile gain of 21 points. The differences between all effect sizes in Table 5.8 were statistically significant (p<.05, two-tailed) from one another.

These findings are consistent with those reported by Smith, Glass and Miller (1980), who found that the overall effect size for the reactivity of the dependent measure was .37. This indicates that the reactivity of dependent measure accounted for a 14 percentile point difference in achievement between experimental and control groups.

Methodological Quality

This moderator variable was coded using a scale with three values: high quality, medium quality, and low quality. The results are reported in Table 5.9.

Table 5.9
Methodological Quality

	ES	n	SD	Gain
High	.65	450	.65	P_{50}-P_{74}
Medium	.62	270	.71	P_{50}-P_{73}
Low	.64	650	.62	P_{50}-P_{74}

The differences in effect sizes reported in Table 5.9 were not statistically significant ($p<.05$, two-tailed), indicating that the methodological quality of the studies had no relationship to the effect sizes that were computed within a given study. These findings are consistent with those reported by Smith et al. (1980) and Lipsey and Wilson (1993). Specifically, Smith reported an effect size of only .06 for the methodological quality of studies. Similarly, Lipsey and Wilson found that studies rated high on methodological quality had an effect size of .40, while studies rated low on methodological quality had an effect size of .37.

Publication Type

This moderator variable was coded using a scale with two values: published studies, and unpublished studies. The results are reported in Table 5.10.

Table 5.10
Publication Type

	ES	n	SD	Gain
Published	.72	320	.67	P_{50}-P_{76}
Unpublished	.64	85	.84	P_{50}-P_{74}

The differences in the effect sizes reported in Table 5.10 were not statistically significant ($p<.05$, two-tailed). Interestingly, though, the fact that published studies had a higher effect size than unpublished studies is not consistent with the problem of publication bias discussed by Rosenthal (1979) and Durlak (1995) — the tendency for studies with low effect sizes not to be published. However, these findings are consistent with those reported by Lipsey and Wilson (1993), who noted that published studies had an effect size of .53 as compared to unpublished studies with an effect size of .39.

General Discussion of Moderator Variables

In general, the moderator variables of most concern (i.e., with the strongest relationship to effect sizes) appear to be the intended user of the instructional technique, student ability, and reactivity of dependent measures. Consequently, readers are cautioned that interpretations regarding all effect sizes reported in subsequent chapters should be tempered in light of the fact that any effect size will surely be affected by the status of subjects relative to these moderator variables. Stated differently, the effect size for any instructional technique is "situated": Instructional techniques might work differently depending on a given student's ability, whether the technique is intended for the teacher or student, or on how sensitive the dependent measure used in the study was to specific outcomes.

Summary

This chapter discussed the general finding that instructional techniques have an overall effect size of .65 across the knowledge domains and the three systems. Such an effect size can be considered dramatically strong and compares well with effect sizes for treatments within the fields of medicine and psychology. This chapter also addressed the findings for eight moderator variables, noting that three of them should be considered when interpreting the results presented in subsequent chapters.

CHAPTER 6

THE KNOWLEDGE DOMAINS

It appears safe to say that knowledge is the outcome that is the central focus of education. As reported earlier in Table 5.1, 2,475 of the 4,057 effect sizes (61%) utilized in this meta-analysis dealt with the knowledge domains. This makes intuitive sense — American educators and the public at large are concerned first and foremost with enhancing students' understanding of new information from traditional subject areas (i.e., the information domain), new mental skills pertinent to traditional subject areas (i.e., the mental process domain), and physical skills that pertain to traditional subject areas (i.e., the psychomotor domain). Additionally, research has shown that the tests commonly used in K-12 education to assess the achievement of individual students, schools, entire districts, or even entire states, focuses primarily on the knowledge domains (Marzano, 1990; Resnick, 1987). It stands to reason, then, that the majority of instructional techniques utilized within education would have as their focus the enhancement of the three knowledge domains.

As articulated in the theory presented in Chapters 2 and 3, the knowledge domains are developed and enhanced via the three systems. That is, knowledge of any type is not simply "poured" into the human mind. Rather, it is acquired, adapted, and utilized by the learner's use of the skills and processes within the cognitive system, *and* the metacognitive system, *and* the self-system. Indeed, any instructional technique utilized by a teacher or a student necessarily utilizes one of more of the three systems. For example, a teacher using some form of advanced organizer is activating the learner's information processing function of idea representation within the cognitive system. A teacher using the techniques of setting explicit instructional goals is tapping into the learner's metacognitive goal-setting function. The teacher utilizing praise as an instructional technique is activating and utilizing students' self-system beliefs about personal attributes. Consequently, instructional techniques that are designed to enhance or utilize knowledge can be classified in terms of the system they primarily employ. Of the 2,475 effect sizes that focused on knowledge, 1,772 effect sizes addressed instructional techniques that utilized processes from the cognitive system, 556 effect sizes addressed instructional techniques that utilized processes inherent in the metacognitive system, and 147 effect sizes addressed instructional techniques that utilized processes from the self-system. The overall effect sizes for the strategies that employed these three systems are reported in Table 6.1.

Table 6.1 illustrates that the overall effect size for instructional techniques focusing on the knowledge domain was .60, indicating that the students' achievement in the three knowledge domains will increase from the 50th percentile to the 73rd if the instructional techniques reviewed in this chapter are utilized by classroom teachers. Taken at face value, the results in Table 6.1 imply that, of the three systems, the self-system has the potential for the greatest impact on student achievement overall, with techniques that utilize skills and processes within the metacognitive system running a close second. Instructional techniques that stimulate the self-system have an average effect size of .74, indicating that they can raise student achievement from the 50th percentile to the 77th percentile. Instructional techniques that stimulate the metacognitive system have an average effect size of .72, indicating that they can raise student achievement from the 50th percentile to the 76th percentile.

Table 6.1
Overall Effects of Instructional Techniques
From the Three Systems on the Knowledge Domains

	ES	n	SD	Gain
Self-system	.74	147	.87	P_{50}-P_{77}
Metacognitive System	.72	556	.81	P_{50}-P_{76}
Cognitive System	.55	1772	.94	P_{50}-P_{71}
Overall	.60	2475	.91	P_{50}-P_{73}

Following the order in which the three systems are described in Chapter 3, instructional strategies that utilized the cognitive system will be considered first in this chapter, then strategies that utilize the metacognitive system, and finally, strategies that utilize the self-system.

Instructional Strategies That Utilize the Cognitive System

As reported in Table 6.1, the overall effect size for techniques that employed the cognitive system was .55. In keeping with the structure of the cognitive system as described in Chapter 3, instructional strategies described in this section are organized into four categories: (1) storage and retrieval processes, (2) basic information processing functions, (3) basic input/output communication processes, and (4) knowledge utilization processes.

Strategies Based on Storage and Retrieval

In all, 135 effect sizes were reported or computed for this category with an average effect size of .83 (n=135, SD=1.02), representing a rise in student achievement in the knowledge domains from the 50th percentile to the 79th when these strategies are employed. The effect sizes for specific storage and retrieval techniques are reported in Table 6.2.

Table 6.2
Instructional Techniques Utilizing
Storage and Retrieval Processes

	ES	n	SD	Gain
Cues	1.13	7	1.10	P[illegible]-P[illegible]
Questions	.93	45	.85	P[illegible]-P[illegible]
Direct Schema Activation	.75	83	.83	P[illegible]-P[illegible]
Overall	.83	135	1.02	P[illegible]-P[illegible]

Cues refers to providing students with a brief preview of the information or skill that is to be addressed in a lesson. Cues can be as simple as a teacher announcing to students the topic or topics that are to be addressed or as complex as providing a few lines of explanation. The intent of such techniques is to provide students with a stimulus to retrieve and activate the knowledge they possess about the topic so that it might be utilized in working memory. This simple strategy had an overall effect size of 1.13, indicating that it can raise achievement by 37 percentile points.

As the name implies, *questions* are specific probes designed by the teacher and asked prior to or during a lesson. Again, the purpose of such questions is to stimulate students to retrieve what they know about the topic to be studied. The effect size of questions was .93, indicating a rise in student achievement of 32 percentile points when questions are used.

Direct schema activation refers to the instructional technique of simply asking students what they know about a topic prior to studying that topic. The effect size of .75 indicates a rise in achievement of 27 percentile points when this strategy is employed.

Strategies Based on Information Processing Functions

The overall effect size for the strategies within this category was .55 (n=1238, SD=.74), indicating a rise in achievement of 21 percentile points if these techniques are used by classroom teachers.

As described in Chapter 3, the specific processes within this category are matching, idea representation, idea production, information screening, information generalization, and information specification. The effect sizes for each of these categories are reported in Table 6.3. Strategies for each type of information processing function are discussed separately.

Table 6.3
Information Processing Functions

	ES	n	SD	Gain
Matching	1.32	51	1.10	P[illegible]-P[illegible]
Idea Representation	.69	708	.92	P[illegible]-P[illegible]
Idea Production	—	—	—	—
Information Screening	—	—	—	—
Information Generalization	.11	237	.65	P[illegible]-P[illegible]
Information Specification	.38	242	.71	P[illegible]-P[illegible]
Overall	.55	1238	.74	P[illegible]-P[illegible]

Matching. The process of matching requires the learner to identify similarities and differences between two or more topics. For example, as a teacher presents students with new information about a region within a lesson on geography, she might ask students to compare and contrast this new information with what they know about regions in general. The overall effect size for strategies within this category was 1.32 (n=51, SD=1.10), indicating a rise in achievement of 40 percentile points (P[illegible] to P[illegible]) if such techniques are used. Among the techniques within this category, the most powerful appears to be having students create analogies linking new content with known content in unique ways. For example, one study reported an effect size as high as 1.65 (n=29, SD=.97) (Stahl and Fairbanks, 1986).

Idea representation. Instructional techniques that utilize the idea representation function require students to generate some type of internal representation for the new knowledge. The overall effect size for instructional techniques in this category was .69 (n=673, SD=.92), indicating an achievement gain of 25 percentile points. Four basic instructional techniques fell within this category: advanced organizers, note taking, graphic representations, and manipulatives. The effect sizes for these techniques are reported in Table 6.4.

Idea production and information screening. No studies were found that addressed instructional techniques that made primary use of these two information processing functions.

Table 6.4
Instructional Strategies that Utilize Idea Representation

	ES	n	SD	Gain
Advanced Organizers	.48	358	.82	P_{50}-P_{68}
Note Taking	.99	36	.85	P_{50}-P_{84}
Graphic Representations	1.24	43	.71	P_{50}-P_{89}
Manipulatives	.89	236	.61	P_{50}-P_{81}
Overall	.70	673	.92	P_{50}-P_{76}

Advanced organizers had an overall effect size of .48, indicating a percentile gain of 18 points. These techniques require the teacher to present some type of description or explanation of the information or skill to be addressed in a lesson. These descriptions are far more detailed than simple cues or questions (discussed in the previous section on storage and retrieval techniques) in that they provide students with an advanced structure or "scaffold" with which to think about and organize the new knowledge. Some advanced organizer techniques involve selected concepts, principles, and generalizations that are presented to students as organizing ideas for the information and skills to be addressed.

Note taking techniques had an overall effect size of .99, indicating a percentile gain of 34 points. These techniques require students to generate personal linguistic representations of the information being presented. Some note taking techniques involve a certain degree of guidance by the teacher — the teacher might stop after a few minutes of the lesson and highlight important topics — while others allow for students to take notes without much teacher guidance.

The instructional technique with the largest effect size within this information processing category was *graphic representations* (ES=1.24). This technique produced a percentile gain in achievement of 39 points (i.e., P_{50}-P_{89}). One of the most effective of these techniques was semantic mapping (Toms-Bronosky, 1980) with an effect size of 1.48 (n=1), indicating a percentile gain of 43 points. With this technique, the learner represents the key ideas in a lesson as nodes (circles) with spokes depicting key details emanating from the node.

Techniques classified as *manipulatives* engage students in some form of physical manipulation of concrete or symbolic artifacts. The overall effect size for these techniques was .89, indicating a percentile gain of 31 points. The use of computer simulation as the vehicle with which students manipulate artifacts produced the highest effect size of 1.45 (n=1), indicating a percentile gain of 43 points.

Information generalization and information specification. The overall effects for information generalization and information specification strategies are reported in Table 6.5.

Table 6.5
Information Generalization and Specification

	ES	n	SD	Gain
Information Generalization	.11	237	.65	P_{50}-P_{54}
Information Specification	.38	242	.71	P_{50}-P_{65}

Information generalization techniques are inductive in nature. They require students to infer generalizations from specific observations or pieces of information. The overall effect size for these techniques was .11, indicating a percentile gain of 4 points. This might be considered comparatively low for the techniques within the information processing category overall. It might also be considered low from the perspective of the relative popularity of inductive strategies (see Joyce and Weil, 1986, for a discussion). That is, given the wide-scale use of instructional techniques that stimulate inductive thinking in students, one would assume that these techniques would have a proven worth.

Information specification techniques require students to make predictions based on known generalizations or principles. The overall effect size for these techniques was .38 — again, relatively low within this overall category. The effects of generalization and specification strategies are described in more depth in the subsequent section of this chapter on concepts, principles, and generalizations.

Basic Input/Output Communication Processes

Although a number of studies were found that addressed the input communication process of reading as well as the output communication process of writing, all of these instructional techniques were designed to enhance students' ability to improve these processes, as opposed to using these processes to enhance students' mastery of knowledge. Therefore, they are discussed in Chapter 7 when instructional techniques are addressed that are specifically designed to enhance students' use of the mental skills within the cognitive system. Stated differently, no studies were found that addressed the impact of the input processes (listening and reading) or the output processes (speaking and writing) on students' knowledge per se.

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Knowledge Utilization Processes

As described in Chapter 3, the processes in this category are problem-solving, decision-making, experimental inquiry, and investigation. The overall effects of utilizing these processes on knowledge are reported in Table 6.6.

Table 6.6
Effects of Knowledge Utilization Processes

	ES	n	SD	Gain
Problem Solving	.54	343	.95	P_{50}-P_{71}
Decision Making	---	---	---	---
Experimental Inquiry	1.14	6	.65	P_{50}-P_{87}
Investigation	---	---	---	---

No studies were found that addressed the impact of the decision-making or investigation processes on knowledge. Problem-solving processes had an effect size of .54, indicating a percentile gain of 21 points. When a teacher utilizes problem-solving to enhance students' understanding of content, students are presented with a situation relative to specific information or a specific skill and then presented with obstacles relative to that information or skill. Such activities require students to think about content in unusual ways, thus deepening their understanding.

Experimental inquiry techniques require students to generate and test hypotheses about content knowledge. Based on six studies identified within this meta-analysis, this type of activity appears to significantly deepen students' understanding of content. Specifically, the effect size for engaging students in the process of experimental inquiry was 1.14, indicating a gain in understanding of knowledge of 37 percentile points.

Instructional Strategies That Utilize The Metacognitive System

As reported in Table 6.1, the overall effect size for instructional techniques that employ the metacognitive system was .72, indicating a percentile gain of 26 points. Following the theory outlined in Chapter 3, the instructional techniques that utilized the metacognitive system were organized into four categories: (1) goal specification, (2) process specification, (3) process monitoring, and (4) disposition monitoring. The overall effect size for instructional techniques that utilize the metacognitive system was .72. Findings for specific functions within this system are reported in Table 6.7.

Table 6.7
Instructional Techniques Utilizing the Metacognitive System

	ES	n	SD	Gain
Goal Specification	.97	53	.74	P_{50}-P_{84}
Process Specification Process Monitoring	.74	488	.91	P_{50}-P_{77}
Disposition Monitoring	.30	15	.65	P_{50}-P_{62}
Overall	.72	556	.81	P_{50}-P_{76}

Goal Specification

The effect size for techniques that engage the goal specification function was .97, indicating a percentile gain of 34 points. The working dynamic behind all techniques within this category is the teacher providing students with specific learning objectives prior to a lesson. Objectives might be in the form of written or verbal statements. It is interesting to note that the specificity with which objectives are presented influences their effect. Intuitively, one might assume that more specific objectives produce higher effect sizes. However, in this study, highly specific behavioral objectives were found to have an effect size of only .12 (Hattie, 1992; Hattie, Biggs and Purdie, 1996). On the other end of specificity continuum are techniques that allow students to have some control over the design of the learning outcomes. This technique was found to have an effect size of 1.21 (Willett and Yamashita, 1983), indicating a percentile gain of 39 points. One might infer that providing students with general instructional objectives that are then adapted by individual students to meet their personal goals is the optimal technique within this category.

Process Specification-Process Monitoring

For a number of instructional techniques it was not possible to determine whether they employed the process specification function of the metacognitive system or the process monitoring function or both. That is, the techniques appeared to utilize both functions and were, therefore, assigned to both categories. The gist of all these techniques was to provide students with feedback relative to the strategies they were using to complete a specific task. It was not clear in the studies reviewed whether students were provided with guidance relative to the most appropriate strategies for the task at hand, although it is a logical assumption that they were. As reported in Table 6.7, the overall effect size for this type of guidance and feedback was .74, indicating a percentile gain of 33 points. However, studies that utilized techniques that focused on highly specific feedback had an effect size of 1.13 (n=1.39, SD=.72), indicating a percentile gain of 37 points (Hattie, 1992).

Disposition Monitoring

Instructional techniques that utilize the disposition monitoring function within the metacognitive system involved wait time and overtly reminding students to activate specific dispositions. The effect size for techniques that employed wait time was .53 (n=2), indicating a percentile gain of 20 points. It is assumed that allowing students to think before responding to a specific stimulus enhances the probability that students will be "mindful" about their thinking and behavior. To this extent, wait time can be considered an indirect technique for enhancing the probability that various dispositions will be activated. A number of studies (n=13) addressed instructional techniques that attempted to directly activate in students the disposition of seeking accuracy. The overall effect size for these studies was .27 (SD=.62), indicating a percentile gain of 11 points.

Instructional Strategies That Utilize the Self-system

As described in Chapter 3, beliefs within the self-system are organized into five different categories: (1) self attributes, (2) self and others, (3) general world view, (4) efficacy, and (5) purpose. As reported in Table 6.1, the overall effect size for instructional techniques that utilize the self-system was .74, indicating a percentile gain of 27 points. The effects of the various categories within the self-system on the knowledge domains are reported in Table 6.8.

Table 6.8
Instructional Techniques Utilizing the Self-system

	ES	n	SD	Gain
Self Attributes	.74	15	.75	P_{50}-P_{77}
Others	.73	122	.89	P_{50}-P_{77}
World View	---	---	---	---
Efficacy	.80	10	.62	P_{50}-P_{79}
Purpose	---	---	---	---
Overall	.74	147	.74	P_{50}-P_{77}

The techniques that activated beliefs about *self attributes* had an effect size of .74, indicating a percentile gain of 27 points. These techniques primarily utilized praise as the vehicle for enhancing students' beliefs about themselves relative to accomplishing specific academic tasks. It is important to note that the use of praise as an instructional technique was both focused and accurate. That is, teachers praised students on their accomplishments relative to specific academic tasks as opposed to providing students with generalized praise. Additionally, praise was used only when warranted — only when students exhibited improved execution or understanding of knowledge. These findings are inconsistent with some of the current educational rhetoric asserting the ineffectiveness of praise (see Kohn, 1992, 1993). Indeed, these findings indicate that praise, when effectively used, can generate a percentile gain of 27 points.

The techniques that activated beliefs about *self and others* had an effect size of .73, indicating a percentile gain of 27 points. Virtually all of these techniques utilized cooperative learning. Johnson, Maruyama, Johnson, Nelson and Skon (1981) reported the overall effect size for cooperation as .73 (n=122). Table 6.9 reports the effect size of variations in the use of cooperative learning.

Table 6.9
Options Within Cooperative Learning

	ES	**n**	**SD**	**Gain**
Cooperation versus Intergroup Competition	.00	9	.63	P_{50}-P_{50}
Cooperation versus Individual Competition	.78	70	.99	P_{50}-P_{78}
Cooperation versus Individual Tasks	.78	104	.91	P_{50}-P_{78}
Individual Competition versus Individual Tasks	.03	48	1.02	P_{50}-P_{51}
Intergroup Competition versus Individual Competition	.37	16	.78	P_{50}-P_{64}
Intergroup Competition versus Individual Tasks	.50	20	.37	P_{50}-P_{69}

Table 6.9 indicates that use of cooperative groups with or without competition produced about the same overall effect size. However, use of cooperative groups had an effect size of .78 when compared with the techniques of: (1) having individual students compete, or (2) having individuals work on tasks independently without competition. Individual competition and having students work on individual tasks without competition produced about the same effect. Intergroup competition had an effect size of .37 when compared with individual competition. Finally, intergroup competition had an effect size of .50 when compared with having students work on tasks individually. In all, then, one might conclude that the simplest form of cooperative learning produces an effect size equal to the more complex variations. For a detailed discussion of the effects of cooperative learning, see Johnson et al., 1981.

No studies were analyzed that utilized instructional techniques activating students' beliefs about the overall nature of the world.

Studies that employed students' beliefs about *self efficacy* primarily dealt with the effort attribution. Within this technique, teachers attempt to reinforce the belief in students that if they "try" (i.e., exert effort), they can succeed at the task at hand. The effect size for such techniques was .80, indicating a percentile gain of 29 points. As is the case with the technique of praise, use of this technique is optimized if it is specific and timely. That is, reinforcing the importance of effort is most effective when it is utilized while students are engaged in a specific task and while they are experiencing difficulties with that task. These findings are consistent with current discussions regarding the importance of providing students with an awareness of the importance of effort on the overall learning process (Stevenson and Stigler, 1992; Weiner, 1972, 1983).

Effects for Specific Types of Knowledge

As described in Chapter 3, knowledge can be thought of as encompassing three domains: information, mental processes, and psychomotor processes. The previous discussion in this chapter discussed the effects of various instructional techniques when they were collapsed across all three domains. That is, in the previous section, no distinction was made regarding the specific knowledge domain for which an instructional technique was intended. In this section, techniques that had differential effects for different types of knowledge are considered. Techniques that focused on the information domain are discussed first, followed by techniques that focused on the mental process domain, and then by techniques that focused on the psychomotor domain.

The Informational Domain

In keeping with the theory presented in Chapter 3, instructional techniques specific to the informational domain are discussed in terms of their effects on the different types of information — concepts, principles, generalizations, episodes, cause/effect sequences, time sequences, facts and vocabulary terms. It was determined that collapsing these types of knowledge into the following three categories was most useful for the purpose of analyzing the research: (1) organizing ideas, (2) details, and (3) vocabulary. The category of organizing ideas includes concepts, principles, and generalizations. The category of details includes episodes, cause/effect sequences, time sequences, and facts. The category of vocabulary includes vocabulary terms only.

Organizing Ideas. As described above, the category of organizing ideas includes concepts, principles, and generalizations. No differences in effect sizes were found between techniques that utilize the self-system or the metacognitive system on students' understanding of organizing ideas, as opposed to the three knowledge domains considered as a group. Consequently, one can assume that instructional techniques presented in Table 6.7 through 6.9 have the same effect when applied specifically to organizing ideas as they do on knowledge in general. However, differences in effect sizes for instructional techniques within the cognitive system were found.

- **Storage and Retrieval:** As reported in Table 6.2, the overall effect size for storage and retrieval techniques across the knowledge domains was .83 (n=135, SD=1.02). The effect size for storage and retrieval techniques when applied specifically to organizing ideas was .69 (n=7, SD=.97), indicating a percentile gain of 26 points. These techniques included both cues and questions, but not direct schema activation. As reported in Table 6.2, cues had an overall effect size of 1.13 across all knowledge domains and questions had an effect size of .93. What, then, might account for the lower effect size of storage and retrieval techniques on organizing ideas? Although one can only speculate, a case might be made that the structure of concepts, generalizations, and principles is dynamic by nature. Once a learner understands a concept, principle, or generalization, she is continually adding new examples to it and making new linkages. Simple storage and retrieval techniques such as cues and questions might not add greatly to this type of processing.

- **Information Processing Functions:** Table 6.10 reports the effect sizes for various information processing functions on organizing ideas as compared to the three knowledge domains considered as a group.

Table 6.10
Information Processing Functions on Organizing Ideas

	All Knowledge		**Organizing Ideas Only**			
	ES	n	ES	n	SD	Gain
Matching	1.32	51	—	—	—	—
Idea Representation	.69	708	.80	115	.91	P_{50}-P_{79}
Idea Production	—	—	—	—	—	—
Information Screening	—	—	—	—	—	—
Information Generalization	.11	237	.11	200	.62	P_{50}-P_{55}
Information Specification	.38	242	.45	212	.74	P_{50}-P_{67}

No studies were identified that utilized matching, idea representation or information screening functions as they relate specifically to concepts, generalizations, or principles. However, studies specifying concepts, generalizations, or principles were found that utilized the idea representation function, the information generalization function, and the information specification function.

Idea representation techniques had a larger effect size for organizing ideas than for knowledge in general (.80 versus .69). While this difference is not significant at the .05 level (two-tailed), it is at the .10 level (one-tailed). It might be the case that structures such as concepts, generalizations, and principles are very complex and require the learner to make a number of interconnections between elements before they are fully understood. Since idea representation techniques engage the learner in complex, elaborative activities, it makes sense that these techniques would have a particularly beneficial effect when utilized with concepts, principles, and generalizations. There were also some differences in effect sizes for specific types of idea representation techniques. Table 6.11 compares the effect sizes for specific representational techniques as they relate to organizing ideas versus knowledge in general.

Table 6.11
Representational Techniques

	All Knowledge		**Organizing Ideas Only**			
	ES	n	ES	n	SD	Gain
Advanced Organizers	.48	358	.78	48	.74	P_{50}-P_{78}
Graphic Representations	1.24	43	1.19	26	.73	P_{50}-P_{88}
Manipulatives	.89	236	.82	45	.42	P_{50}-P_{79}

Of the differences in effect sizes reported in Table 6.11 between techniques applied to knowledge in general versus organizing ideas in particular, the only technique for which the effect size difference was statistically significant was the use of advanced organizers ($p<.05$, two-tailed). Again, it would make sense that this technique would be more beneficial when utilized with knowledge that requires a great deal of organization by the learner, given that it provokes students to make connections among various aspects of information.

Information generalization and information specification techniques produced about the same effect sizes when applied to organizing ideas as opposed to knowledge in general. However, this finding might be a consequence of the fact that the vast majority of studies identified within this category were designed specifically to address concepts, generalizations, and principles. In other words, few studies were found that addressed the use of information generalization and information specification techniques on knowledge in general. Almost all techniques within these categories focused in organizing ideas.

As Table 6.10 indicates, the effect of using information generalization techniques on students' understanding of concepts, principles, and generalizations was relatively small (ES=.11). However, information specification techniques had a significantly higher ($p<.025$, one-tailed) effect size on organizing ideas than did information generalization techniques (.45 vs .11). This might indicate that once students understand concepts, principles, and generalizations, asking them to apply this knowledge via deductively-oriented, information specification techniques produces enhanced understanding. In fact, when those studies that described specific deductive techniques were isolated, the effect sizes reported in Table 6.12 emerged.

Table 6.12
Teaching for Information Specification

	ES	n	SD	Gain
Explicit instruction	2.55	2	---	P_{50}-P_{99}
Deductive strategies designed to enhance application of organizing ideas	1.16	10	.72	P_{50}-P_{88}
Deductive strategies that utilized formal logic	.98	3	.35	P_{50}-P_{83}

As Table 6.12 indicates, two studies reported an effect size of 2.55 for direct instruction in concepts, principles, and generalizations, indicating a percentile gain of 49 points. Ten studies reported an average effect size of 1.16 (indicating a percentile gain of 38 points) for techniques that used deductive strategies designed to help students apply their knowledge of concepts, principles, and generalizations. Finally, of those studies that used deductive strategies, three used formal logic. These produced an effect size of .98 indicating a percentile gain of 34 points. This implies that the optimum instruction techniques to employ with concepts, generalizations, and principles is to present students with those organizing ideas in a direct fashion (as opposed to asking students to induce them) and then have students apply that general knowledge to specific situations. Additionally, it appears that the effects of these knowledge application activities can be enhanced if they are accompanied by instruction in general and specific techniques for deductive reasoning.

Details

As described previously, the category of details includes facts, time sequences, cause/effect sequences, and episodes. Only instructional techniques that use the idea representation function could be found that applied specifically to details as opposed to knowledge in general. The effect sizes from these studies are reported in Table 6.13.

Table 6.13
Instructional Techniques for Details

	All Knowledge		**Organizing Ideas Only**		**Details**			
	ES	n	ES	n	ES	n	SD	Gain
Advanced Organizers	.48	358	.78	48	.56	36	.74	P_{50}-P_{71}
Explanation or Narration	---	---	---	---	.63	66	.56	P_{50}-P_{74}

Table 6.13 indicates that advanced organizers had about the same effect for details as was reported for knowledge in general (.56 vs .48 respectively). However, the effects of advanced organizers on details was significantly smaller ($p<.05$, one-tailed) than the effects of advanced organizers on organizing ideas (ES=.78), again supporting the hypotheses that advanced organizers produce stronger understanding for more complex types of information. Table 6.13 also reports an effect size of .63 (indicating a percentile gain of 24 points) for instruction techniques that involve the teacher presenting students with a detailed description or narrative (i.e., story) regarding the facts, time sequences, episodes, and so on that are the subject of instruction. This implies that details are best presented to students directly in a format that is rich in specifics, much like a story.

Vocabulary

A few studies were found that employed instructional techniques specific to vocabulary that utilized the self-system and the metacognitive system. The effects of these techniques on vocabulary as compared with the effects on knowledge in general are reported in Table 6.14.

Table 6.14
Self-system and Metacognitive System Techniques for Vocabulary

	All Knowledge		**Vocabulary**			
	ES	n	ES	n	SD	Gain
Self-system Praise	.74	15	1.76	1	---	P_{50}-P_{96}
Metacognitive System Goal Specification	.97	53	.79	1	---	P_{50}-P_{79}

The use of praise to enhance vocabulary learning had an effect size of 1.76, as opposed to an effect size of .74 when the technique was considered across all types of knowledge. However, given that the effect size of 1.76 was based on one study only, one cannot conclude that praise has a differential effect on vocabulary, as opposed to knowledge in general. The same might be said for the effect of identifying specific goals for vocabulary instruction. One should not conclude that this technique produces different effects for vocabulary instruction given that the effect size of .97 is based on a single study.

The vast majority of studies in vocabulary instruction focused on techniques that utilized the idea representation function within the information processing category of the cognitive system. The effect sizes for these techniques are reported in Table 6.15.

Table 6.15
Idea Representation Techniques for Vocabulary

	ES	n	SD	Gain
Idea Representation (Overall)	1.14	327	.74	[illegible]
Definition or Description	1.53	110	.46	[illegible]
Context	1.59	10	.52	[illegible]
Balanced	1.66	25	.52	[illegible]
Student Generated	1.67	62	.61	[illegible]
Semantic Mapping	2.27	3	1.01	[illegible]
Training in Visual Memory	1.13	14	.61	[illegible]
Key Word	.59	34	.54	[illegible]

When comparing the effect sizes represented in Table 6.15 with those reported in Table 6.5 (i.e., idea representation techniques across all types of knowledge), one is immediately struck by the relatively large effect sizes for vocabulary instruction. If one does not include the comparatively low effect of the key word method (.59), the range of effect sizes for idea representation techniques specific to vocabulary instruction is 1.13 to 2.27.

Based on Table 6.15, it appears that direct instruction in vocabulary is highly effective whether one uses an approach in which students are presented with a definition or description of the target word (ES=1.53), whether students determine definitions from context (ES=1.59), whether students generate their own definitions (ES=1.67), or whether a balanced approach is utilized (ES=1.66).

The role of nonlinguistic processing of information about vocabulary terms appears particularly important as evidenced by the 2.27 effect size for semantic mapping that indicates a percentile gain of 49 points. Indeed, simply training students in techniques to enhance visual memory has an effect size of 1.13, indicating a percentile gain of 37 points. The strategy with the lowest effect size was the key word method .59, indicating a percentile gain of 22 points. Paradoxically, this method makes heavy use of visual memory (i.e., nonlinguistic processing of information). However, with this approach, the images students are asked to create to remember the meanings of new words are highly artificial, which might account for its comparatively low effect size as compared with the other techniques in Table 6.15 that are more meaning-based and constructive in nature.

A related set of findings relative to vocabulary instruction was the effect of the number of exposures students have to new words. These findings are reported in Table 6.16.

Table 6.16
Exposures to New Words

	ES	n	SD	Gain
One Exposure	1.01	.4	.64	P_{50}-P_{84}
Multiple Exposures	1.60	20	.75	P_{50}-P_{94}
Multiple Repetitions	2.17	35	.63	P_{50}-P_{98}

As reported in Table 6.16, one exposure to the meaning of a new word produced an effect size of 1.01 indicating a percentile gain of 34 points. Multiple exposures to a word, without necessarily reinforcing the meaning of the new word after each exposure (i.e., multiple exposures), produced an effect size of 1.60 indicating a percentile gain of 45 points. However, when students were repeatedly exposed to a newly learned word and meanings were discussed with each repetition (i.e., multiple repetitions), the effect size increased to 2.17, indicating a percentile gain of 49 points. A related finding was that the modal time required for exposure to a word was 1.5 minutes. This implies that the following might be an effective general technique for teaching vocabulary:
(1) present students with a definition or description of the new word, (2) have students represent that description in some way preferably using some type of nonlinguistic representation, and (3) have students review the meanings and representations for the word. This process should take no more than five minutes per word.

The Mental Process Domain

Only 45 effect sizes were unique to the domain of mental processes. The effects on the mental process domain of instructional techniques that use the three systems are reported in Table 6.17 as they compare with techniques that employ those same systems but are applied to knowledge in general.

Table 6.17
Effects on the Mental Process Domain

	All Knowledge		Information		Mental Process			
	ES	n	ES	n	ES	n	SD	Gain
Self-system	.74	147	.73	145	1.18	2	---	P_{50}-P_{88}
Metacognitive System	.72	556	.64	402	.84	4	.73	P_{50}-P_{80}
Cognitive System	.55	1772	.51	1681	.58	39	.65	P_{50}-P_{72}

None of the differences in effect sizes reported in Table 6.17 was significant at the .05 level (two-tailed). Consequently, one should not interpret the higher effect sizes for instructional techniques employing the self-system and metacognitive system on mental process knowledge as an indication that these techniques are more effective on this particular type of knowledge. What is noteworthy, however, is that the pattern of relative strength of effect sizes remains constant across different types of knowledge — self-system instructional techniques produce a larger effect than do metacognitive techniques and cognitive techniques.

Relative to the self-system, the primary technique was the use of praise to enhance students' self-attributions relative to their ability to learn a new mental skill. In terms of the metacognitive system, the instructional technique employed within the four studies reflected in Table 6.17 was the identification of specific learning objectives prior to instruction. The instructional techniques that utilized the cognitive system were the use of advanced organizers (ES=.60; n=15) and the use of manipulatives (ES=.56; n=24). Both of these instructional techniques used the basic information processing function of idea representation.

The Psychomotor Domain

Only 30 effect sizes dealt specifically with the psychomotor domain. Additionally, all of these effect sizes came from the same study (Tannebaum and Goldring, 1989) and all dealt with the utility of identifying specific learning objectives prior to instruction — a technique employing the goal specification function within the metacognitive system. The overall effect size for this technique was .66 (SD=.75), indicating a percentile gain of 25 points. Table 6.18 reports the effect size for this technique for various types of psychomotor skills.

Table 6.18
Effects on Different Types of Psychomotor Skills

	ES	n	SD	Gain
Ball Skills	.80	7	.14	P_{50}-P_{79}
Gymnastics	.52	3	.17	P_{50}-P_{70}
Track and Field	.51	3	.24	P_{50}-P_{70}
Motor Development	.67	2	.24	P_{50}-P_{75}

Although the effect sizes in Table 6.18 appear very different, only that for ball skills was significantly different ($p<.05$, two-tailed) from that for gymnastics and track and field. No explanation was hypothesized as to why the identification of specific learning goals would be higher for ball skills than for gymnastics or track and field.

Conclusion

The findings reviewed in this chapter offer some clear direction for educators. First, the relatively strong effects of techniques that employ the self-system and the metacognitive system should be noted, especially since techniques that utilize these systems have traditionally either been ignored or, at worst, discounted. For example, Garcia and her colleagues (Garcia and Pintrich,1991, 1993; Pintrich and Garcia, 1992) note that the importance of the self-system in the learning process, although recognized by psychologists, has been virtually excluded from the instructional equation by educators. Additionally, much of the "popular" literature critiquing current educational practice seems to downplay and even condemn attempts by teachers to bolster students' beliefs about sense of self (see Hirsch, 1987, 1996; Bennett, 1992). The overall effect size for techniques that utilize the self-system (.74) indicates that targeting this system should be a key aspect of instructional design. As Bandura notes:

> A fundamental goal of education is to equip students with self-regulatory capabilities that enable them to educate themselves. Self-directedness not only contributes to success in formal instruction, but also promotes lifelong learning. (1997, p. 174)

Where instructional techniques that employ the self-system are not rare, those that use the metacognitive system are certainly common fare among educators. The overall effect size of .72 for such techniques certainly warrants this emphasis. However, outside of education, such techniques are commonly the subject of concern and even ridicule. For example, E. D. Hirsch has strongly criticized the use of instructional techniques that utilize the metacognitive system. He refers to instructional techniques that employ the metacognitive system as EOM (an Emphasis on Metacognition). Hirsch lists the following criticisms:

- EOM may interfere with the orderly development of adaptive problem-solving strategies.
- EOM may carry severe opportunity costs by usurping subject matter instruction.
- EOM may overload working memory and thus impair rather than help learning.
- All of these potential drawbacks may have the most adverse effects on slow or disadvantaged learners. (Hirsch, 1996, p. 139)

The results of this meta-analysis do not support Hirsch's criticisms. Rather, these findings indicate that metacognitive strategies, along with strategies that employ the self-system, are primary ingredients for improving student achievement.

The overall effect size for techniques that utilize the cognitive system are not as impressive as the overall effect size for techniques that utilize the metacognitive and self-systems (i.e., .55 versus .72 and .74 respectively - see Table 6.1). However, specific techniques within the cognitive systems appear to be quite powerful. For example, techniques that help students retrieve what they already know about a topic prior to studying it are very impactful (e.g., the effect size for cues was 1.13) as are techniques that require students to compare and contrast new knowledge with familiar topics (ES=1.32). Asking students to represent new knowledge in some graphic/nonlinguistic format has a strong impact on learning (ES=1.24), as does having students generate and list hypotheses about new knowledge (ES=1.14).

Finally, some conclusions can be drawn about instructional techniques for specific types of knowledge. The best way to teach organizing ideas — concepts, generalizations, and principles — appears to be to present those constructs in a rather direct fashion (ES=2.55) and then have students apply the concepts, generalizations, and principles to new situations (ES=1.16). Details are best taught by presenting the information in story fashion or a richly descriptive context (ES=.63). Vocabulary is best taught by first presenting students with a definition or description (ES=1.53) or having them determine the meaning of words from content (ES=1.59), or both (ES=1.66). At some point, students should be asked to generate their own definition (ES=1.27) and represent this definition using some type of semantic map (ES=2.27). Mental process and psychomotor knowledge should be enhanced by addressing students' beliefs regarding their ability to learn such processes and skills, providing models, asking students to practice the various aspects of the process or skill while providing specific feedback.

CHAPTER 7

THE COGNITIVE SYSTEM

The instructional techniques reviewed in this chapter have as their focus the improvement of the various processes within the cognitive system. These techniques stand in contrast to those categorized in Chapter 6 as "employing" the cognitive system. To illustrate the difference, an instructional technique that is designed to *use* the cognitive process of idea representation to enhance student understanding of a particular concept would be discussed in Chapter 6, because the technique is intended to enhance knowledge by activating the cognitive process of idea representation. A technique that is designed to improve students' ability to represent ideas would be discussed in this chapter. In one case, the instructional technique activates and utilizes the mental skill of idea representation to enhance knowledge. (The technique is reviewed in Chapter 6.) In the other case, the instructional technique actually improves students' competence in the mental skill of idea representation and is, therefore, reviewed in Chapter 7.

In keeping with the theory described in Chapter 3, instructional techniques that focused on the cognitive system are discussed in terms of the four categories of processes within that system: (1) storage and retrieval, (2) information processing function, (3) input/output function, and (4) knowledge utilization.

Storage and Retrieval

No studies were analyzed that addressed instructional techniques designed specifically to enhance students' abilities to utilize the storage and retrieval functions.

Information Processing Functions

Only nineteen effect sizes addressed instructional techniques designed to enhance the various information processing functions. These studies dealt with three instructional techniques: (1) the use of specific objectives, (2) wait time, and (3) feedback.

Identifying Specific Objectives

As described in Chapter 6, the identification of specific learning objectives is a strategy that employs the goal specification function within the metacognitive system. This technique produced an effect size of 1.37 (n=3; SD=.63), indicating a percentile gain of 41 points. As applied to the cognitive system, this technique presents students with specific goals in terms of enhancing cognitive mental skills. For example, in a given lesson, a teacher might announce to students that the goal of the lesson is to improve their ability to represent knowledge in nonlinguistic modes (i.e., an idea representation technique) or to improve their ability to make specific predictions (i.e., an idea specification technique).

Wait Time

The use of wait time employs the disposition monitoring function of the metacognitive system. This instructional technique produced an effect size of 1.27 (n=2), indicating a percentile gain of 40 points. It is assumed that wait time stimulates the disposition monitoring function of the metacognitive system. That is, it is assumed that as students work on improving a specific mental skill within the cognitive system, the teacher's use of wait time increases the probability that students will seek clarity or resist impulsivity as they practice that skill.

Feedback

The instructional technique of feedback employs the process specification and process monitoring functions of the metacognitive system. This technique produced an effect size of 1.13 (n=14; SD=.61). This means that when students were given feedback on the type of strategy to use and how well they were using it to improve a specific type of cognitive process, the average percentile gain in achievement was 37 points.

The Impact of the Metacognitive System on the Cognitive System

It is interesting to note that all techniques that addressed the information processing functions within the cognitive system used the metacognitive system. An interesting way of depicting the results is presented in Table 7.1.

Table 7.1
Effects of the Metacognitive System on the Cognitive System

	ES	n	SD	Gain
Goal Specification Techniques	1.37	3	.63	P_{50}-P_{91}
Disposition Monitoring	1.27	2	---	P_{50}-P_{90}
Process Specification and Process Monitoring Techniques	1.13	14	.61	P_{50}-P_{87}
Overall	1.18	19	.61	P_{50}-P_{88}

Although the number of studies analyzed for this category of cognitive processes was relatively small (n=19), one might conjecture that the metacognitive system is a powerful tool in enhancing student skill in the information processing functions.

Input/Output Communication Functions

Relative to the input/output communication functions, no studies were analyzed that addressed instructional techniques for listening or speaking. However, a number of studies were found that addressed reading and writing.

Reading

Two studies addressed techniques that employed the self-system. The average effect size for these was .89, indicating a percentile gain of 31 points. Both studies used praise to enhance students' beliefs about themselves relative to the reading process (i.e., self-attributes).

A number of studies employed techniques that activate the metacognitive system. Four studies used techniques that focused on the goal specification function within the metacognitive system. The basic approach used in these studies was to provide students with clear instructional goals relative to the reading process. The average effect size for studies employing this technique was 1.09 (SD=.25), indicating a percentile gain of 36 points.

Other studies that were specific to reading employed instructional techniques that activated the process specification or process monitoring functions within the metacognitive system. The average effect sizes for these studies are displayed in Table 7.2.

Table 7.2
Techniques Utilizing the Process Specification
and Process Monitoring Functions

	ES	n	SD	Gain
Feedback (general)	.48	15	.62	P_{50}-P_{68}
Feedback (steps in reading process)	1.00	24	.81	P_{50}-P_{84}
Strategy Instruction (decoding)	.58	25	.92	P_{50}-P_{72}
Visual Memory Training (information processing)	1.04	25	.61	P_{50}-P_{84}
Summarizing Training (information processing)	1.03	104	.74	P_{50}-P_{84}
Discourse Characteristics (retrieval)	.57	1	---	P_{50}-P_{72}
Topic Information (retrieval)	.60	231	.52	P_{50}-P_{73}

The techniques displayed in Table 7.2 are organized by the five aspects of the reading process described in Chapter 3: (1) overall steps in the reading process, (2) the written language decoder, (3) the information processing function, (4) retrieval of knowledge about discourse types, and (5) retrieval of information about the topic.

The first category of instructional techniques reported in Table 7.2 had an effect size of .48, indicating a percentile gain of 28 points. Studies which were used in the calculation of this effect size did not identify the specific aspect of reading on which they focused. They simply indicated that they utilized metacognitive techniques to enhance the reading process. Studies that were coded as focusing on metacognitive control of the overall steps within the reading process had an average effect size of 1.00, indicating a percentile gain of 34 points. Apparently, teaching students that reading involves an overall flow of activity and techniques for monitoring that process enhances its effectiveness.

Instructional techniques that focused on decoding had an effect size of .58, indicating a percentile gain of 22 points. This effect size is not terribly large when compared with the other effect sizes reported in Table 7.2. However, analysis of different approaches to teaching decoding illustrates some differences. These are presented in Table 7.3.

Table 7.3
Decoding Technique

	ES	n	SD	Gain
Sounding and blending as part of overall process	.56	2	---	P_{50}-P_{71}
Sounding and blending in isolation	1.63	3	1.21	P_{50}-P_{95}
Whole word recognition	.30	15	.22	P_{50}-P_{62}
Letter/sound relationships	.74	7	.94	P_{50}-P_{77}

Instructional techniques that focused on sounding and blending provided students with strategies for determining the sound of words not immediately recognized. It is interesting to note that when these metacognitive sounding and blending strategies were embedded in the overall process of reading, the effect size was .56 (n=2), indicating a percentile gain of 21 points. However, when these strategies are taught in isolation, the effect size was 1.63, indicating a percentile gain of 45 points. Certainly the skill of sounding and blending must be employed within the overall process of reading. However, it might be the case that the skill is complex enough that it is best initially learned in isolation so that working memory is not over-taxed with the demands of the other aspects of reading.

In contrast to the techniques that stressed sounding and blending, techniques that focused on recognizing words as a whole had an effect size of only .30, indicating a percentile gain of 12 points. Finally, instructional techniques that focused solely on letter/sound relationships had an effect size of .74, indicating a percentile gain of 27 points. These techniques do not provide students with a strategy for decoding words as much as basic information with which students might design their own strategies. The relatively strong effect size for these techniques is consistent with the research supporting the importance of students possessing a basic understanding of English orthography (Adams, 1990).

The next two techniques displayed in Table 7.2 employed the information processing function of idea representation. Techniques that provided students with metacognitive strategies for using visual memory had an effect size of 1.04, indicating a percentile gain of 35 points. Presumably, these strategies help students represent information they are reading in nonlinguistic form. Instructional techniques that focused on summarizing strategies had an effect size of 1.03, indicating a percentile gain of 25 points. Presumably, these strategies help students represent information they are reading in linguistic form. From these findings, one might infer that idea representation is a key aspect of the reading process.

The last two categories of techniques depicted in Table 7.2 address retrieval of information. Techniques that enhance students' retrieval and use of information about discourse types had an effect size of .57, indicating a percentile gain of 22 points. Techniques that enhance students' retrieval and use of information about the topic had an effect size of .60, indicating a percentile gain of 23 points.

Some reading studies addressed techniques that attempt to enhance the idea representation information processing function during reading using pictorial aids. These studies were considered as a group in themselves (as opposed to grouping them with the idea representation techniques in Table 7.2) because they did not employ the metacognitive system. Rather, they were considered manipulations of the environment designed to stimulate idea presentation in students. These studies had an average effect size of .46 (n=16; SD=.20), indicating a percentile gain of 28 points. Table 7.4 displays the differential effects of techniques within this category.

No techniques listed in Table 7.4 were significantly different from any other techniques. However, it is interesting to note that the immediate use of pictorial aids had a greater effect size than did the delayed use.

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Table 7.4
Pictorial Aids

	ES	n	SD	Gain
Line Drawings	.50	6	.19	P_{50}-P_{69}
Shaded Drawings	.45	6	.22	P_{50}-P_{67}
Photographs	.30	3	.14	P_{50}-P_{62}
Immediate	.51	6	.16	P_{50}-P_{70}
Delayed	.33	1	---	P_{50}-P_{63}

Writing

Writing was the only output function for which studies were analyzed. Virtually all of the writing studies used techniques that employ the metacognitive system. Effect sizes for the various metacognitive writing techniques are reported in Table 7.5.

Table 7.5
Metacognitive Techniques For the Writing Process

	ES	n	SD	Gain
Goal Specification: Setting explicit goals	.71	9	.29	P_{50}-P_{76}
Process Specification and Process Monitoring: Overall writing process	.59	20	.24	P_{50}-P_{72}
Process Specification and Process Monitoring: Language Encoder	.35	5	.08	P_{50}-P
Process Specification and Process Monitoring: Informal processing functions	---	---	---	---
Process Specification and Process Monitoring: Retrieval of information about the medium	.22	17	.08	P_{50}-P_{58}
Process Specification and Process Monitoring: Retrieval of information about the topic	.56	6	.08	P_{50}-P_{71}

Table 7.5 indicates that the technique of identifying specific instructional goals for students relative to writing yielded an effect size of .71, indicating a percentile gain of 26 points. This technique employs the goal specification function within the metacognitive system. The remaining techniques depicted in Table 7.5 are organized around the five aspects of the writing process described in Chapter 3: (1) steps in the overall writing process, (2) the written language encoder, (3) information processing, (4)

retrieval of information about the medium, and (5) retrieval of information about the topic. All techniques that relate to these five aspects of writing employed the process specification and process monitoring functions of the metacognitive system.

The technique of providing students with an overall strategy for the writing process and providing feedback on that strategy produced an effect size of .59, indicating a percentile gain of 22 points. The effect size for this technique is much lower than the effect size for the same technique applied to reading (i.e. 1.00 for reading — see Table 7.2). No reason for this differential effect is offered here. Indeed, the theory base surrounding reading and writing would suggest that teaching and providing feedback on the overall process involved should have virtually identical effects on reading and writing. As an interesting aside, a number of studies (n=19) used the technique of simply engaging students in free writing without any instruction or feedback relative to the overall process involved. This strategy produced an effect size of .17, only (SD=.07) indicating a percentile gain of seven points. Utilizing the theory presented in this book, such a technique would be classified as an "indirect instruction" at best. In fact, if one defines instruction as a teacher intervening in the learning process, this approach would necessarily be classified as a "non-instructional technique." The low effect size might indicate that the metacognitive system requires overt priming by a teacher to affect student learning of complex processes such as writing.

Five studies dealt with the technique of sentence combining. Within this theory, sentence combining is classified as an encoding strategy — that is, it is designed to enhance students' ability to encode language in proper syntactic form. The effect size for these studies was .35 (SD=.08), indicating a percentile gain of 24 points. Another technique that was classified as focused on the encoding function within writing was instruction in grammar. Presumably, the more familiar a student is with correct grammar, the easier it is to translate thoughts into syntactically correct language. Paradoxically, the effect size for direct instruction in grammar was a negative .29 (n=5; SD=.08), indicating that such instruction decreased students' percentile rank from the 50th percentile to the 39th percentile. For some reason, instruction in grammar does not help students produce higher quality writing. Perhaps an overemphasis on grammar distracts students from more important aspects of the writing process.

No studies that addressed any of the information processing functions relative to writing were found. However, studies were found that addressed students' ability to retrieve and use information about the medium of written language and the topic that is the focus of writing. Table 7.5 indicates that using instructional techniques that focus on students' understanding of the medium of written language had an effect size of .22, indicating a percentile gain of 8 points. These techniques all dealt with providing students with an understanding of the characteristics of quality in written language. Instructional techniques that focused on students' understanding and analysis of the writing topic had an effect size of .56, indicating a percentile gain of 21 points.

Knowledge Utilization Processes

Of the four processes within this category — decision making, problem solving, experimental inquiry, and investigation — studies were found that related to the direct enhancement of only one, experimental inquiry. Twenty studies dealt with techniques that employed the self-system to enhance the process of experimental inquiry. All of these techniques focused on students' beliefs about purpose. Specifically, these techniques attempted to illustrate to students how the experimental inquiry process might be useful in their lives. These techniques produced an average effect size of .92, indicating a percentile gain of 32 points. All other studies dealt with techniques that utilized one or more aspects of the metacognitive system.

A number of studies utilized instructional techniques that employed the process specification and process monitoring functions of the metacognitive system to enhance the overall process involved in the experimental inquiry process. The effect sizes for these techniques are reported in Table 7.6.

Table 7.6
Techniques Utilizing Process Specification and
Process Monitoring Functions to Enhance Overall Process

	ES	n	SD	Gain
Teaching Overall Process (general)	.80	75	.75	P_{50}-P_{79}
Teaching Steps	.67	151	.62	P_{50}-P_{75}
Teaching Heuristics	1.17	45	.61	P_{50}-P_{88}
Indirect	.46	59	.85	P_{50}-P_{67}

As Table 7.6 indicates, 75 studies were classified as "general." Techniques within these studies were classified as general because they provided few specifics regarding the approach they took to enhancing the experimental inquiry process. These techniques produced an average effect size of .80 indicating a percentile gain of 29 points.

Other studies were identified that described instructional techniques in more detail. Studies in which the experimental inquiry process was taught as a series of steps or in an algorithmic fashion had an effect size of .67, indicating a percentile gain of 25 points. However, studies in which the experimental inquiry process was taught as a set of more general heuristics had an effect size of 1.17, indicating a percentile gain of 38 points. Interestingly, studies that employed an indirect or implicit approach to experimental inquiry had the lowest effect size of .46, indicating a percentile gain of 16 points. With these techniques, students were engaged in the experimental inquiry process but received indirect instruction only in that process. When these indirect techniques emphasized a "hands-on" approach to the process, the effect size rose to .62 (n=32; SD=65), indicating a percentile increase of 23 points.

The techniques in a number of studies were classified as specific to the process monitoring function of the metacognitive system as opposed to the process specification and process monitoring, as is the case with the techniques reported in Table 7.6. The effect sizes for instructional techniques specific to process monitoring are reported in Table 7.7.

Table 7.7
Techniques Utilizing the Process Monitoring
Function of the Metacognitive System

	ES	n	SD	Gain
Feedback (general)	.94	43	.52	P_{50}-P_{83}
Feedback (heuristics)	1.20	17	.62	P_{50}-P_{88}
In class only	.41	21	.72	P_{50}-P_{66}
Homework	1.06	18	.48	P_{50}-P_{85}
Limited topic	.50	28	.71	P_{50}-P_{69}
Variety of topics	.64	6	.63	P_{50}-P_{74}
Immediate	.86	5	.71	P_{50}-P_{80}
Delayed	1.39	6	.62	P_{50}-P_{92}

The overall effect size for studies that simply described the instructional technique as "providing feedback" on the use of the experimental inquiry process was .94, signifying a percentile gain of 33 points. Studies which specified feedback on heuristics as opposed to a set of steps had an average effect size of 1.20, indicating a percentile gain of 38 points. This is quite consistent with the findings reported in Table 7.6. Apparently teaching experimental inquiry as a set of general rules or heuristics produces stronger impact than does teaching the process as a set of rigid steps, although the latter approach produces substantial gain in student utilization of experimental inquiry.

Table 7.7 also indicates that when the experimental inquiry process was practiced in class only, the effect size was .41, indicating a percentile gain of 16 points. However, when students were required to practice the process at home in the form of homework, the effect size rose to 1.06, indicating a percentile gain of 25 points. A difference in effect size is also evident for the extent to which the experimental inquiry process was applied to limited versus varied topics. When the experimental inquiry process was applied to limited topics (i.e., the teacher restricted the topics that were addressed), the effect size was .50, indicating a percentile gain of 19 points. When the experimental inquiry process was applied to varied topics (i.e., the teacher encouraged students to utilize the process with a wide variety of topics, sometimes of their own choosing), the effect size was .64, indicating a percentile gain of 24 points. The timing of feedback on the process also appears important. Immediate feedback produced an effect size of .86, indicating a percentile gain of 30 points. However, delayed feedback produced an effect size of 1.39, indicating a percentile gain of 41 points.

Conclusion

As is the case with instructional techniques that address the knowledge domains, some of the studies that address the cognitive system use the self-system. The overall effect of techniques that used the self-system was .92 (n=22, SD=.65), indicating a percentile gain of 32 points. Again, it would appear that the self-system as a tool for enhancing learning — this time learning of strategies to enhance cognitive processing — presents great potential for educators.

The overall effect of metacognitive techniques on the cognitive system was .75 (n=524, SD=.65), indicating a percentile gain of 27 points. Although the effect size for techniques that employ the metacognitive system was less than techniques that employed the self-system, the metacognitive system appears to be the "engine" for enhancement of the mental processes within the cognitive system. That is, the vast majority of instructional techniques designed to enhance student competence in the skills within the cognitive system employed the metacognitive system. Of the various functions within the metacognitive system, process specification and process monitoring appear to be the two most commonly employed. Providing students with a strategy or strategies for the processes involved within the cognitive system appears to be quite impactful. It also appears that presenting students with general heuristics for the overall processes within the cognitive system is more effective than presenting students with steps that must be executed in a rigid order or presenting students with an algorithmic strategy.

CHAPTER 8

THE METACOGNITIVE AND SELF-SYSTEMS

The instructional techniques reviewed in this chapter were designed to enhance student competence in the processes within the metacognitive system and the self-system. Again, it is important to note that the techniques discussed in this chapter, like those discussed in Chapter 7, were not designed to improve students' competence in the knowledge domain.

The Metacognitive System

Relatively few studies were identified that focused on instructional techniques designed to enhance the metacognitive system per se. The effects of instructional techniques on the metacognitive system are reported in Table 8.1.

Table 8.1
Effects of Instructional Techniques
on the Metacognitive System

	ES	n	SD	Gain
Verbalization (Metacognitive: Process Monitoring)	1.38	2	---	P_{50}-P_{92}
Information about Disposition (Metacognitive: Process Monitoring and Information Specification	.89	1	---	P_{50}-P_{81}

The technique of verbalization produced an effect size of 1.38, indicating a percentile gain of 42 points. Here the process monitoring function of the metacognitive system is being used to enhance the performance of the metacognitive system as a whole. Additionally, teaching students about the nature and function of dispositions enhanced their ability to monitor those dispositions. This technique produced an effect size of .89. It is interesting to note that both of these techniques use the process monitoring function of the metacognitive system to enhance the performance of that very system. However, the presentation of information also uses the information specification function of the cognitive system. That is, presenting students with generalizations and principles about metacognition leads them, via activation of the information specification function within the cognitive system, to conclusions about the metacognitive system.

A set of 48 studies on experimental inquiry indicated that engaging students in tasks that involve this process had an effect size of .51 on metacognition (n=48, SD=.78), indicating a percentile gain of 69 points. Apparently the process of experimental inquiry (i.e., generalizing and listing hypothesis) is robust and complex enough that it both stimulates students' use of the metacognitive system and enhances it.

The Self-system

Techniques that focused on the self-system addressed three of the five areas of that system: (1) self-attributes, (2) self and others, and (3) efficacy. No techniques were identified that directly or indirectly address (4) world view, and (5) beliefs about purpose within the self-system.

Self-attributes

A number of studies addressed instructional techniques that affected students' beliefs about their self-attributes. The effect sizes for these instructional techniques are reported in Table 8.2.

Table 8.2
Instructional Techniques Focused on Self-attributes

	ES	n	SD	Gain
Verbalization (Metacognitive: Process Monitoring)	.99	1	---	P_{50}-P_{84}
Feedback (Metacognitive: Process Monitor)	.18	11	.53	P_{50}-P_{57}
Overt Objective (Metacognitive: Goal Monitor)	.86	2	---	P_{50}-P_{80}
Experimental Inquiry (Cognitive: Knowledge Use)	.35	75	.62	P_{50}-P_{64}
Overall	.34	89	.61	P_{50}-P_{63}

The four categories of instructional techniques reported in Table 8.2 all used the metacognitive system. The use of verbalization to reinforce self-attributes had an effect size of .99, indicating a percentile gain of 34 points. This technique employs the process monitoring function of the metacognitive system. Apparently, the act of verbalizing their thoughts while monitoring the execution of a complex task provides students with insights into the effect of their beliefs about their attributes on their performance.

The technique of providing students with feedback also stimulates the process monitoring function of the metacognitive system and has the indirect effect of enhancing students' beliefs about self-attributes (ES=.18). Two other techniques that had indirect effects on self-attribution were setting overt instructional objectives and the process of experimental inquiry. Apparently, the act of a teacher setting explicit learning objectives has a positive effect on students' beliefs about their self-attributes (ES=.82). One can only speculate as to why this might be the case. Perhaps providing students with explicit learning objectives renders them more efficient at tasks which, in

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turn, makes them perceive themselves as more competent. Similarly, engaging students in the process of experimental inquiry generated an effect size of .35 on self-attribution. Again, one might speculate that the process of experimental inquiry, when rigorously approached, produces a level of learning that enhances students' perceptions of their ability.

All of the techniques discussed in this section can be considered highly indirect. That is, the instructional techniques are primarily designed to stimulate systems other than the self-system. For some reason, these techniques also stimulate the self-system. Given that three of the techniques reported in Table 8.2 are designed to engage the metacognitive system, one might surmise that the metacognitive system provides "automatic" access to the self-system.

Self and Others

The overall effect sizes for instructional techniques that altered students' perceptions relative to self and others was .52 (n=2), indicating a percentile gain of 20 points. These techniques used direct presentation and analysis of information as the primary instructional tool. The assumption underlying these techniques is that if students are well informed about the effects of beliefs about self and others, they will alter those beliefs if necessary. Based on the theory presented in this book, one might conclude that these techniques rely on the information specification function of the cognitive system to affect beliefs within the self-system. That is, once students learn generalizations and principles about their beliefs, the information specification function within the cognitive system leads them to logical conclusions about changes they should make in their own beliefs.

Efficacy

Some instructional techniques addressed changes in students' beliefs about efficacy. These techniques relied on presenting students with information about the importance of effort. Again, it can be assumed that such information stimulates the information specification function of the cognitive system and leads students to conclusions about necessary changes in their beliefs regarding the importance of effort. Additionally, the techniques within this category used the strategy of monitoring self talk, thus stimulating the process monitoring function of the metacognitive system. In summary, these techniques used both the information specification function of the cognitive system and the process monitoring function of the metacognitive system to change students' beliefs relative to efficacy. The average effect size for these techniques was 1.00 (n=3; SD=.52), indicating a percentile gain of 34 points.

Techniques From Psychotherapy

Although not usually considered part of the repertoire of instructional techniques available to teachers, some psychotherapeutic techniques appear to have direct application to classroom instruction. The effect sizes for those types of therapy that are most adapted to classroom practice are reported in Table 8.3.

Table 8.3
Psychotherapeutic Techniques That Have
Application to Classroom Instruction

	ES	n	SD	Gain
Behavioral Modification Techniques (Metacognitive: Process Monitoring)	.73	201	.67	P_{50}-P_{77}
Cognitive Behavioral Modification (Metacognitive: Process Monitoring and Information Specification)	1.13	127	.83	P_{50}-P_{87}
Techniques Involving Rational Examination of Emotions (Metacognitive: Process Monitoring and Information Specification)	.68	50	.54	P_{50}-P_{75}
Techniques Involving Career Counseling (Information Specification)	.65	59	.58	P_{50}-P_{74}
Techniques Involving Reflection of Students' Feelings (Metacognitive: Indirect Process Monitoring)	.14	9	.38	P_{50}-P_{55}
Overall	.82	446	.62	P_{50}-P_{79}

Behavioral modification techniques rely on the metacognitive process monitor function to change students' behaviors as well as beliefs within the self-system. These techniques produce an effect size of .73, indicating a percentile gain of 27 points. Cognitive behavioral modification techniques add the presentation of information to the techniques employed within strict behavioral modifications. Here students are taught about the self-system (i.e., provided with information) along with techniques for monitoring their behavior (i.e., techniques for utilizing the process monitoring function of the metacognitive system). Consequently, they employ the information specification function of the cognitive system and the process monitoring function of the metacognitive system to alter students' beliefs. The average effect size for these techniques was 1.13, signaling a percentile gain of 37 points. Techniques that focused on a rational examination of emotions produced an average effect size of .68, indicating a percentile gain of 25 points. These techniques involve the presentation of information about the impact of emotions on the self-system, along with strategies that use the process monitoring function of the metacognitive system. Career counseling techniques are information based — they present students with information on careers and future options, thus utilizing the information specification function of the cognitive system. These techniques had an average effect size of .65, signaling a percentile gain of 24 points. Finally, techniques that involved reflecting students' emotions back to them via what might be described as active listening, had an average effect size of .14, indicating a percentile gain of 5 points. These techniques might be considered indirect in that they seek to stimulate the metacognitive system which, in turn, has an effect on the self-system.

Conclusions about Techniques For Metacognitive and Self Systems

Both the metacognitive and self-system seem most influenced by instructional techniques that employ the idea specification function of the cognitive system in conjunction with the process monitoring function of the metacognitive system. The combined effect on the metacognitive and self-systems for techniques that utilize the combined strategy was .99 (n=186, SD=.72), indicating a percentile gain of 34 points. These combination strategies provide students with an awareness of the manner in which their minds work (specifically the metacognitive and self-systems) and then require students to monitor their mental activity.

Non-intervention Studies

A number of reports were found that addressed the relationship between various elements of the theory presented in this book, but did not involve instructional techniques. That is, these studies addressed the general influence one element of the mind characteristically has on another element, without the benefit of intervention by a teacher. To illustrate, a study might report the influence of the self-system on the information domain without describing instructional techniques that teachers might use to enhance this relationship. To some extent, then, such studies might be considered validation studies for the overall theory presented in this book.

In all, 1,730 effect sizes were computed or reported that addressed relationships between various aspects of the mind. The general findings for these studies are reported in Table 8.4.

Of immediate interest in terms of Table 8.4 is the fact that all studies addressed the relationship between the self-system and other elements of the mind. That is, no studies were found that did not involve the effect of the self-system.

Table 8.4 indicates that the overall effect of the self-system on the metacognitive system, the cognitive system, and the knowledge domains was .80, indicating that various beliefs withing the self-system can alter achievement relative to the functioning of these other elements by 20 percentile points.

Table 8.4
Interrelationships Among Various Theory Components

Relationship	ES	n	SD	Gain
Self on Metacognitive System	.99	434	.62	P_{50}-P_{84}
Self on Cognitive System	.79	1047	.72	P_{50}-P_{79}
Self on Knowledge	.52	249	.58	P_{50}-P_{70}
Overall	.80	1730	.68	P_{50}-P_{70}

The effect of the self-system on the metacognitive system was the largest (.99), indicating a percentile gain of 34 percentile points. The effects of specific aspects of the self-system on the metacognitive system are reported in Table 8.5.

Table 8.5
Effects of Self-system on Metacognitive System

	ES	n	SD	Gain
Others	1.22	23	.61	P_{50}-P_{89}
World View	.83	226	.71	P_{50}-P_{80}
Efficacy	1.29	3	.72	P_{50}-P_{90}
Purpose/Value	1.88	2	---	P_{50}-P_{97}

Table 8.5 indicates that one's beliefs about others has an effect size of 1.22 on the utilization of the metacognitive system indicating a gain of 39 percentile points. One might interpret this to mean that perceptions of others has a large effect on whether one chooses to actively set goals, identify strategies, and so on regarding tasks that involve those about whom opinions are held. If certain individuals or groups are considered unimportant by an individual, he will probably not make effective use of the metacognitive system when engaged in tasks that involve or relate to those individuals or groups. Conversely, if certain individuals or groups are considered important, then he will make effective use of the metacognitive system with tasks that involve or relate to those individuals or groups.

World view had an effect size of .83, indicating a percentile gain in the use of the metacognitive system of 30 points. Again, if one views a certain situation as important, he is more apt to make effective use of the metacognitive system. An effect of 1.29 was found for beliefs about efficacy on the metacognitive system. This effect size indicates a percentile gain of 40 points. Presumably, if one believes she has the power or potential to affect a situation, she will make more effective use of the metacognitive system.

Finally, the largest effect on the metacognitive system was found for beliefs about purpose. Perception of how relevant a task is in terms of beliefs about overall life purpose had an effect size of 1.88 on the utilization of the metacognitive system, indicating a percentile gain of 47 points. Apparently, the extent to which an individual perceives a task as related or unrelated to his beliefs about overall life purpose dramatically effects the extent to which metacognitive functions are effectively utilized.

The overall effect size of the self-system on the functioning of the cognitive system was .79. This indicates that specific beliefs within the self-system can increase the functioning of the cognitive system by 29 percentile points. The effects of specific aspects of the self-system on cognition are reported in Table 8.6.

Table 8.6
Effects of Self-system on Cognitive System

	ES	n	SD	Gain
World View	.89	498	.72	P_{50}-P_{81}
Efficacy	.86	50	..62	P_{50}-P_{80}

Table 8.6 indicates that one's beliefs about the world has a potential effect on the cognitive system of .89, indicating a percentile gain of 31 points. That is, certain beliefs about how the world operates can enhance the functioning of the cognitive system by a factor of 31 percentile points. Similarly, one's beliefs regarding efficacy has an effect size of .86 on the functioning of the cognitive system. That is, one's beliefs about the extent to which a situation can be changed has the potential of increasing the effectiveness of cognitive functioning relative to that situation by 30 percentile points.

The overall effect of the self-system on the knowledge domain was .52, indicating a percentile gain of 20 points. The effects of specific aspects of the self-system in the knowledge domain are reported in Table 8.7.

Table 8.7
Effects of the Self-system on Knowledge

	ES	n	SD	Gain
Self-attributes	.61	112	.34	P_{50}-P_{73}
Efficacy	.70	8	.65	P_{50}-P_{76}
Purpose/Value	.63	1	---	P_{50}-P_{74}

Table 8.7 indicates that beliefs about self-attributes have an average effect size of .61 on the knowledge domain, indicating a percentile gain of 23 points. If a student believes he is good at mathematics, for example, this belief can enhance his performance in mathematics. Beliefs about efficacy had an average effect size of .70, indicating a percentile gain of 26 points. If a student believes she has the power to change her performance in mathematics, for example, this belief can enhance her performance in mathematics. Finally, beliefs about life purpose and value had an effect size of .63, indicating a percentile gain of 24 points. If a student believes that mathematics is important relative to basic life purposes, this belief can enhance his performance in mathematics.

It is interesting to consider the overall effects of the five categories of beliefs within the self-system. The average effect sizes for the five categories of beliefs across all other systems and the knowledge domains are reported in Table 8.8.

Table 8.8
Effects of the Five Categories of Beliefs
Across Other Systems and the Knowledge Domains

	ES	n	SD	Gain
Self-attributes	.61	112	.34	P_{50}-P_{73}
Self and Others	1.22	23	.61	P_{50}-P_{89}
World	.87	724	.69	P_{50}-P_{81}
Efficacy	.86	61	.64	P_{50}-P_{80}
Purpose	1.37	4	.78	P_{50}-P_{92}

Table 8.8 supports the strong effect of one's beliefs about purpose on the overall functioning of the other systems and knowledge. If a task is consistent with perceived life purposes, all other systems and knowledge are activated. Table 8.8 also attests to the importance of beliefs about others when engaged in group tasks. Positive beliefs about the importance and value of members of a group affect the extent to which one brings to bear the skills within the metacognitive and cognitive systems as well as the information skills and processes within the various knowledge domains. It is interesting to note that beliefs regarding self-attributes had the lowest effect size of the five belief categories (ES=.61), although it was still substantial. Perhaps it is the case that positive beliefs about efficacy, others, purpose, and so on can overcome negative self-attribution.

Conclusions about Non-intervention Studies

The non-intervention studies provide strong support for the influence of the self-system on all other aspects of the mind. These studies indicate that student beliefs might be the controlling factor in their behavior. If one couples these findings with those reported in Chapter 6, one can easily infer that educators should pay particular attention to instructional techniques that address student beliefs.

CHAPTER 9

GENERAL DISCUSSION

This chapter presents a general discussion of the findings described in Chapters 5 through 8. First, some very general observations and opinions about the findings are presented, followed by a discussion of implications for classroom instruction. Finally, a description is provided of an emerging paradigm of an expert teacher, followed by a discussion of the need for further research.

Observations and Opinions

As a result of the meta-analysis, the author has made some observations and formed some overall opinions about the research on instruction.

The Self-system Appears to Be the Control Center for Human Behavior

The five categories of beliefs within the self-system appear to control all other aspects of human thought and action. One's beliefs can affect the functioning of the metacognitive and cognitive systems as well as the knowledge domains. Additionally, it seems to be the case that positive self-system beliefs can be both stimulated by teachers and directly altered by specific instructional techniques.

One possible reason why the techniques that employ the self-system are so robust is that they seem to provide access to affective representations. As explained in Chapter 2, all forms of information and skill within the knowledge domains, the cognitive system, the metacognitive system, and the self-system are represented in one or more of three possible forms: linguistic, nonlinguistic, and affective. Some of the instructional techniques reviewed in this study focused on specific representation modalities. Table 9.1 depicts the average effect sizes for instructional techniques that used the various representational modalities, cross-referenced with the three systems and the knowledge domains.

Table 9.1
Representational Modalities, the Three Systems, and Knowledge

	Knowledge	Cognitive	Meta-cognitive	Self	Overall
Linguistic	ES=.59 n=2195	ES=.73 n=966	ES=.55 n=51	ES=.69 n=153	ES=.63 n=3365
Nonlinguistic	ES=.94 n=280	ES=1.04 n=25	----	----	ES=.95 n=305
Affective	----	----	----	ES=.86 n=387	ES=.86 n=387

As Table 9.1 illustrates, no instructional techniques that focused on the knowledge domains, the cognitive system, or the metacognitive system addressed the affective representation of thought. Techniques that focused on the affective modality were used with the self-system only. However, such techniques appear to produce powerful results. Specifically, the average effect size of .86 for these techniques indicates a percentile gain of 31 points. Given the discussion in Chapter 2 about the pervasive nature of affect in human thought and human functioning, it seems expedient to develop instructional techniques that help students better understand the nature of emotions and how they affect one's behavior. To this end, Goleman's (1995) work on emotional intelligence appears to be a good start.

The Metacognitive System is the Engine of Learning

Where the self-system is the center of control of the mind, the metacognitive system appears to be the primary vehicle for learning. Specifically, instructional techniques that employed the metacognitive system had strong effects whether they were intended to enhance the knowledge domains, the mental process within the cognitive system, the beliefs and processes within the self-system, or the processes within the metacognitive system itself. Table 9.2 depicts the effect sizes of instructional techniques that employ the metacognitive system on the various elements of the mind.

Table 9.2
Effects of Techniques Employing the Metacognitive System

	On Knowledge	**On Cognition**	**On Meta-cognition**	**On Self**	**Overall**
Techniques employing goal specification	ES=.97 n=53	ES=1.01 n=150	——	——	ES=1.00 n=203
Techniques employing process specification and/or process monitoring	ES=.74 n=480	ES=.73 n=970	ES=.55 n=50	ES=.71 n=348	ES=.72 n=1848
Techniques employing disposition monitoring	ES=.30 n=15	ES=1.27 n=2	ES=.89 n=1		ES=.44 n=18

As illustrated in Table 9.2, instructional techniques employing the goal specification functions had an effect size of 1.00 across the knowledge domains and the three systems, indicating a percentile gain of 34 points. The simple act of setting clear instructional goals, then, produces significant gains in student learning. Added to this, providing feedback to students regarding the strategies they have selected to complete a task and the effectiveness with which they are utilizing those strategies produces an overall effect size of .72, indicating a percentile gain of 26 points. An analysis of Table 9.2 further indicates that this type of feedback is particularly useful when the focus of instruction is process-oriented. Indeed, the vast majority of instructional techniques that addressed the cognitive system employed the process specification and process monitoring functions of the metacognitive system. Specifically, 970 (Table 9.2) of the 991 (Table 5.1) instructional techniques that addressed the cognitive system used these two functions of the metacognitive system. Findings similar to these led Hattie (1992) to conjecture that setting clear instructional goals for students and providing them with feedback regarding their progress toward these goals is one of the most straightforward and powerful instructional techniques a teacher can employ: ". . .the most powerful, single moderator that enhances achievement is feedback. The simplest prescription for improving education must be 'dollops of feedback'" (Hattie, 1992, p. 9).

Implications

At least three relatively straightforward implications about classroom instruction can be inferred from this meta-analysis:

- Implication #1: Teachers should identify knowledge and skills that are targets of instruction.
- Implication #2: Teachers should identify and use specific instructional techniques for specific instructional goals.
- Implication #3: Teachers should regularly use instructional techniques that apply to all types of instructional goals.

Identify Knowledge and Skills That Are Targets of Instruction

The theory upon which this study was based appears to hold up quite well from at least two perspectives. First, the constructs of the self-system, metacognitive system, cognitive system, and the knowledge domains appear to be useful organizers for the research on instruction, in that they allow for the categorization of instructional techniques into meaningful groups. Techniques that address one system or domain have distinguishing characteristics from those addressing another system or domain. Additionally, as described in Chapter 2 and 3, the research supporting the existence of the various components of these systems and domains is strong.

All of this implies that it is important for classroom teachers to be specific about the types of knowledge and/or processes that are to be the targets of classroom instruction, so that specific instructional techniques can be used. At an operational level, it appears that teachers should be able to answer the questions in Figure 9.1 relative to any unit of instruction in their classroom.

What, if any, are my instructional goals relative to enhancing students'. . .

Knowledge Goals

Information:
- understanding of key vocabulary terms
- understanding of important details
- understanding of organizing ideas

Mental Processes:
- ability to perform subject-specific algorithms
- ability to perform subject-specific tactics
- ability to perform subject-specific processes

Psychomotor Processes:
- ability to perform subject-specific psychomotor skills

Cognitive Goals

Storage and Retrieval:
- ability to store and retrieve knowledge

Basic Information Processing:
- ability to identify similarities and differences
- ability to represent knowledge in a variety of forms
- ability to analyze the validity and reasonableness of new knowledge
- ability to generate inferences using new knowledge
- ability to apply conceptions, generalizations, and principles to new situations

Input/Output Processes:
- ability to comprehend information presented orally
- ability to comprehend information presented in written or symbolic terms
- ability to communicate information in oral form
- ability to communicate information in written or symbolic form

Knowledge Utilization:
- ability to make decisions
- ability to solve problems
- ability to generate and test hypotheses using experimental inquiry
- ability to investigate issues

Metacognitive Goals

- ability to set explicit goals
- ability to identify strategies to accomplish goals
- ability to monitor progress toward goals

- ability to monitor and control:
- accuracy and precision
- clarity
- impulsivity
- intensity of engagement
- focus

Self Goals

- understanding their beliefs about their personal attributes
- understanding their beliefs about others
- understanding their beliefs about how the world works
- understanding their beliefs about purpose and what is important in life
- understanding their beliefs about what can and cannot be changed—what they can and cannot do

Figure 9.3. Questions to Clarify Instructional Goals.

From the perspective of the theory presented in this study, all of these questions represent valid instructional targets. Indeed, if one accepts the findings of this study, a strong case can be made for the fact that instructional goals that pertain to the self-system should be an educational priority. Unfortunately, it is probably safe to say that instructional goals that relate to the self-system are highly controversial in public education. For example, much of the controversy over what is commonly referred to as "Outcome-based Education" is focused on the perceived emphasis within that movement on self-system related instructional goals. The apparent objection to such an emphasis was that the self-system inherently addresses values which are not an appropriate target for instruction. (For a discussion, see Gaddy, Hall and Marzano, 1996.)

It is certainly true that the self-system addresses values, particularly those beliefs within the self-system that deal with life purpose. Whether values are or are not an appropriate instructional target for public education is not self-evident and, consequently, most probably a subject that should be debated further. However, the findings of this meta-analysis strongly imply that targeting the self-system can produce substantial improvements in students' achievement within the knowledge domains, as well as students' utilization of the processes within the metacognitive and cognitive systems.

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Use Specific Instructional Techniques for Specific Instructional Goals

Once a classroom teacher is clear about the instructional goal within a unit, he or she should identify specific instructional techniques for specific types of knowledge. Even though this meta-analysis cannot yet be considered complete, it suggests that the instructional techniques identified in Figure 9.2 are most effective for the various possible instructional goals.

Knowledge Goals

If the instructional goal is to enhance students' understanding of vocabulary terms and phrases:

- Provide students with a brief description or informal definition of each word or phrase.
- Have students describe the words or phrases in their own words and represent their personal descriptions using some form of nonlinguistic modality (e.g., pictures, semantic maps, charts).
- Occasionally have students review the terms and phrases making refinements in their representation.

If the instructional goal is to enhance students' understanding of details:

- Present the details in some form of story or elaborated description.
- Have students represent their understanding of the details in linguistic (e.g., notes, outlines) and nonlinguistic formats (e.g., pictures, semantic maps, charts, etc.).

If the instructional goal is to enhance students' understanding of organizing ideas (e.g., concepts, generalizations, principles):

- Demonstrate the organizing ideas to students in concrete terms.
- Have students apply the concept, generalization, or principle to new situations.

If the instructional goal is to enhance students' ability to perform subject-specific algorithms:

- Present the various steps in the algorithm.
- Have students practice the algorithm paying particular attention to how it might be improved.

If the instructional goal is to enhance students' ability to perform subject-specific tactics or processes:

- Present students with general rules or heuristics as opposed to specific steps.
- Have students practice the tactic or process paying particular attention to how it might be improved.

If the goal is to enhance students' ability to perform psychomotor skills:

- Present students with a model of the psychomotor skill.
- Have students practice the skill paying particular attention to how it might be improved.

Cognitive Goals

If the goal is to enhance students' ability to store and retrieve knowledge:

- Provide students with strategies that use the representation of knowledge in nonlinguistic forms (e.g., mental images).

If the goal is to enhance students' ability to identify similarities and differences, to analyze the reasonableness of new knowledge, to generate inferences about new knowledge, or to apply organizing ideas:

- Provide students with a set of heuristics, as opposed to steps regarding the processes involved.
- Have students practice the heuristics, paying particular attention to how they might be improved.

If the goal is to enhance students' ability to represent knowledge in a variety of forms:

- Provide students with strategies for representing knowledge linguistically.
- Provide students with strategies for representing knowledge nonlinguistically.

If the goal is to enhance students' ability to comprehend information presented orally (i.e., listening):

- Present students with a set of heuristics, as opposed to steps for the overall process of listening.
- Have students practice the heuristics, paying particular attention to how they might be improved.

If the goal is to enhance students' ability to comprehend information presented in written form:

- Provide students with information and strategies designed to enhance their ability to decode print. Have them practice the strategies, paying particular attention to how they might be improved.
- Provide students with a set of heuristics for the overall process of reading. Have students practice the heuristics, paying particular attention to how they might be improved.
- Provide students with strategies for activating what they know about a topic prior to reading.
- Provide students with strategies for summarizing information they have read.
- Provide students with information about the various text formats they will encounter.

- Provide students with strategies for representing what they have read in nonlinguistic form and as mental images.

If the goal is to enhance students' ability to present information in oral form (i.e., speak):

- Present students with information about the various conventions used in different situations.
- Provide students with heuristics for the overall process of speaking in various situations, and have them practice the heuristics, paying particular attention to how they might be improved.
- Provide students with strategies for analyzing a topic in depth prior to speaking about it.

If the goal is to enhance students' ability to present information in written form:

- Provide students with heuristics for the overall process of writing, and have students practice these heuristics, paying particular attention to how they might be improved.
- Present students with strategies for encoding thought into print.
- Present students with strategies for analyzing a topic in depth prior to writing about it.
- Provide students with information about the various discourse formats in which they will be expected to communicate.

If the goal is to enhance students' ability to make decisions, solve problems, or perform investigations:

- Provide students with heuristics for the overall processes of decision-making, problem-solving, and investigation, and have them practice the heuristics, paying particular attention to how they might be improved.
- Provide students with strategies for using what they know about the topics that are the focus of problems, decisions, and investigations.

If the goal is to enhance students' ability to engage in experimental inquiry:

- Provide students with heuristics for the overall process of experimental inquiry, and have them practice the heuristics, paying particular attention to how they might be improved.
- Provide students with strategies for generating and testing hypotheses.
- Have students apply the experimental inquiry process to a variety of situations.

Metacognitive Goals

If the goal is to enhance students' ability to set explicit goals, identify strategies for accomplishing goals, or monitor progress toward goals:

- Have students verbalize their thinking as they engage in these functions, and analyze the effectiveness of their thought processes.
- Present students with information about the nature and importance of using the metacognitive system.

If the goal is to enhance students' ability to monitor their use of the various dispositions:

- Provide students with explicit information about the nature and function of the various dispositions.

Self Goals

If the goal is to enhance students' understanding of and control of their beliefs about self-attributes, self and others, the nature of the world, efficacy, or purpose:

- Have students verbalize their thinking relative to these areas.
- Have students make linkages between specific beliefs and specific behaviors in their lives.
- Have students identify those behaviors they wish to change.
- Provide students with strategies for altering their thinking relative to the behaviors they would like to change.

Figure 9.4. Instructional techniques for Specific Instructional Goals.

Use Instructional Techniques That Apply to All Types of Instructional Goals

In addition to the specific instructional strategies listed in Figure 9.2, this meta-analysis suggests that the following instructional techniques should be used by teachers regardless of the instructional goals that are the focus of a unit of instruction.

(1) When presenting new knowledge or processes to students, provide them with advanced ways of thinking about the new knowledge or processes prior to presenting them.

(2) When presenting students with new knowledge or processes, help them identify what they already know about the topic.

(3) When students have been presented with new knowledge or processes, have them compare and contrast it with other knowledge and processes.

(4) Help students represent new knowledge and processes in nonlinguistic ways as well as linguistic ways.

(5) Have students utilize what they have learned by engaging them in tasks that involve experimental inquiry, problem-solving, and (presumably) decision-making and investigation.

(6) Provide students with explicit instructional goals and give them explicit and precise feedback relative to how well those goals were met.

(7) When students have met an instructional goal, praise and reward their accomplishments.

(8) Have students identify their own instructional goals, develop strategies to obtain their goals, monitor their own progress and thinking relative to those goals.

(9) When presenting new knowledge or processes, help students analyze the beliefs they have that will enhance or inhibit their chances of learning the new knowledge or processes.

An Emerging Picture

For at least the past fifteen years, educational researchers have been attempting to identify an effective pedagogical model or paradigm that educators can use to optimize the learning experience in the classroom. In 1986, Shulman described the "missing paradigm" in education as one that bridged the gap between content knowledge and instructional techniques. That same year, Berliner published *In Pursuit of the Expert Pedagogue* (1986) which, among other things, laid down a challenge to educational researchers to organize the extant research on instruction to provide a usable instructional model for practitioners. In 1990, Leinhart attempted to organize the research into a model of an effective lesson. This meta-analysis adds to these and other previous efforts and provides an emerging picture of effective teaching and the effective teacher.

The effective teacher is one who has clear instructional goals. These goals are communicated both to students and to parents. Ideally, the instructional goals address elements of the knowledge domains as well as the cognitive, metacognitive, and self-system. Even if the instructional goals focus on the knowledge domains only (as is frequently the case in public education), the teacher still uses instructional techniques that employ the cognitive system, the metacognitive system, and the self-system. Perhaps, above all, the teacher understands the interrelationships among the knowledge domains, the cognitive system, the metacognitive system, and the self-system, and uses that understanding to make the myriad of instructional decisions that occur in a single lesson.

Direction of Further Research

Although informative, this meta-analysis falls significantly short of its original goal to provide a comprehensive review of the research on instruction. Even though over 4,000 effect sizes were included in this effort, it is estimated that at least triple this number will be needed to provide highly stable estimates of the effect sizes for each of the various instructional techniques reviewed. Therefore, readers are cautioned that these findings should be considered "indications" of the conclusions that might be drawn from an exhaustive review of the research on instruction. On the other hand, readers should feel confident that these findings represent a sound basis for classroom teachers to begin adapting and experimenting with the instructional techniques described in this report.

In 1999, a follow-up report is planned that will incorporate additional studies in the analysis and report findings in a more user-friendly manner which will facilitate applying the appropriate method in the classroom.

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